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ESSAYS ON THE PATHO-PHYSIOLOGY OF THE HIGHER NERVOUS ACTIVITY

ACCORDING TO I. P. PAVLOV AND HIS SCHOOL

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TRANSLATED BY S. BELSKY

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IVAN PETROVICH PAVLOV
My Dear and Unforgettable Teacher

THE AUTHOR

I. P. PAVLOV

PREFACE TO THE FIRST EDITION

Some forty-five to fifty years ago Ivan Petrovich Pavlov laid the foundations of the theory of the higher nervous activity, which has become one of the greatest treasures of Russian science.

Pavlov's theory is the result of collective work, unmatched for the way in which it was planned and organized, for its consistent purposefulness and which was carried on for almost thirty-five years by a large body of scientific workers—the Pavlov school—under his brilliant guidance.

Among Pavlov's immediate assistants, men and women who helped to create his theory, were I. F. Tolochinov, G. P. Zeliony, N. I. Krasnogorsky, L. A. Orbeli, Y. V. Volborth, M. A. Ussievich and M. K. Petrova. In subsequent years some of his closest collaborators abandoned the theory of the higher nervous activity and created their own trends and schools; others worked hard for decades on the further development of the physiology, and later, also of the pathology of the cerebral hemispheres.

But research in the field of the theory of the higher nervous activity directed by I. P. Pavlov developed in a particularly big way after the Great October Socialist Revolution.

Shortly before his death Pavlov, in the well-known address to the youth, stated: "Our country is opening up boundless vistas for scientists, and, let it be said, science in our country receives generous backing, the utmost backing."

A most active part in the elaboration of the theory of the higher nervous activity under Pavlov's direct

guidance was taken over a long period by G. P. Zeliony, M. K. Petrova, Y. V. Volborth, N. A. Podkopayev, Y. P. Frolov, D. S. Fursikov, O. S. Rosenthal, K. M. Bykov, V. I. Pavlova, V. V. Rickman, L. A. Andreyev, M. A. Ussievich, V. V. Stroganov, V. V. Yakovleva, B. N. Bierman and others.

Among Pavlov's younger collaborators an especially big contribution to the theory of the higher nervous activity was made by E. A. Asratyan, G. V. Skipin, A. O. Dolin, L. O. Seewald, S. V. Klestchov, I. O. Narbutovich and K. S. Abuladze.

M. K. Petrova was Pavlov's closest assistant and the most active continuer of his teaching on the patho-physiology of the higher nervous activity; an enormous amount of work was done by her in this field. Being a clinician and therapist, she devoted much energy to bringing the experimental patho-physiology of the animal higher nervous activity into closer contact with the clinic, with practical medicine. Substantial facts were also added to the theory of conditioned reflexes by I. P. Razenkov and A. D. Speransky.

The human higher nervous activity has become the object of experimental study thanks to N. I. Krasnogorsky; a physiologist and pediatrist, Krasnogorsky has been working for more than forty years on problems of the physiology and patho-physiology of the higher nervous activity in the field of pediatrics, at first single-handed and later in collaboration with his numerous co-workers.

A number of Pavlov's disciples, who worked under his guidance, have created their own original trends and schools; however, in many cases these are but far-flung ramifications of the theory of the higher nervous activity, which Pavlov himself over a long period regarded as the main direction.

In his *Lectures on the Work of the Cerebral Hemispheres*, published in 1927, Pavlov summed up all the

experimental data relating to the patho-physiology of the higher nervous activity which had been obtained by that time; he also made the first steps in applying the theory of the higher nervous activity to man and in its utilization in clinical medicine.

Since then more than twenty years have passed, but still we do not see any review or summary (except Pavlov's last articles), even any attempt to sum up the rich and valuable material obtained by the laboratories and clinics of Pavlov during his lifetime and after his death.

On the occasion of the centenary of Pavlov's birthday (September 27, 1949) the author of this book takes the liberty of attempting to fill this gap in the patho-physiology of the higher nervous activity; his aim is to expound in a number of essays the basic achievements of this young branch of science and to give an outline of its development in the Pavlov school (including its ramifications) up to our time.

In the preface to the third edition of the *Lectures on the Work of the Cerebral Hemispheres* published in November 1935, Pavlov wrote: "My new systematic exposition of the *whole* of our experimental material in the shape of one book will require much labour, and I regard it as my last scientific task. It will take years to complete this work. If only fate will be so kind as to preserve for me at my age the vigour that will enable me to carry out this important duty of my life!"

Death prevented Pavlov from carrying out this desire.

In the *Essays on the Patho-Physiology of the Higher Nervous Activity* the author tries, to the best of his ability, to carry out, even in small measure, Pavlov's will; the author regards this as his duty to Russian science and to his late teacher.

April 27, 1949

INTRODUCTION

Pavlov is not only the creator of the physiology of the cerebral hemispheres, that is, of the physiology of the higher nervous activity, but also the founder of the pathological physiology of the higher parts of the central nervous system.

As we know, these parts

a) secure the adaptation, equilibration of the organism as an integral whole with the external environment and create the highest and most complex forms of its interrelation with the surrounding world;

b) effect the highest regulation and correlation of all physiological processes taking place in the internal medium of the organism, of all vegetative and metabolic functions, and finally,

c) effect the integration and the fluent and fluctuating co-ordination of the whole external and internal (somatic and visceral-vegetative) vital activity of the organism, i.e., secure its most complex functional unity.

These three basic functions of the cerebrum are closely interconnected. Consequently, in cases of pathological disturbances of the activity of the higher parts of the central nervous system, it is difficult to assume a fully isolated impairment of one of these functions; usually such disturbances spread, to a greater or lesser degree, in all three directions, concentrating mainly only in one of them.

An unceasing development and interaction of nervous processes take place in the wakeful, active cortex under the influences coming from the external world and the internal medium of the organism; at the same time there is a continuous change of the dynamic correlations between the cortex and the lower parts of the central nervous system.

"The infinite fluctuations in both the outer and inner mediums of the organism," Pavlov said in 1927, "each of which is reflected in definite states of the nervous cells of the cerebral cortex, may become separate conditioned stimuli."*

The cortical activity effects a most complex interaction of the highly mobile and changeable reflection of the surrounding environment with the reflection of the organism's internal medium, i.e., with the reception of all somatic and vegetative (proprioceptive and interoceptive) stimuli coming into the cortex from the skeleto-muscular apparatus and internal organs and constituting the principal foundation of "self-perception."

In the cerebral cortex in the course of such interaction there takes place a continuous development of new links, connections, associations between the external and internal influences, on the one hand, and various somatic and vegetative activities, on the other; there also arises a process of inhibition of these connections when, temporarily or permanently, they cease to comply with the demands which the external and internal mediums make upon the nervous system.

Whereas in animals the activity of the cerebrum described above is determined biologically, in man this de-

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* I. P. Pavlov, *Lectures on the Work of the Cerebral Hemispheres*, Russ. ed., State Publishing House, 1927, p. 48. (Hereafter this work is referred to as *Lectures*.)

termination is not only of a biological, but first and foremost of a social nature.

We shall deal with the question of the specific properties of the human higher nervous activity later on.

The study of changes in the activity of the cerebral cortex (as well as in its interaction with the lower parts of the brain, developing under the influence of noxious, morbific factors, i.e., changes that are observed under various pathological conditions, constitutes a most important task confronting the patho-physiology of the higher parts of the central nervous system.

In 1930 Pavlov said: "Three chief problems must be studied in the higher nervous activity, in the behaviour of the animal: 1) the unconditioned, most complex special reflexes, the work of the basal ganglia as the foundation of the external activity of the organism; 2) the activity of the cortex, and 3) the way in which these ganglia and the cortex are connected and interact."*

Consequently, when roughly detailing the tasks of the patho-physiology of the higher parts of the central nervous system, one can say that they include the study of pathological disturbances of the higher subcortical functions (disturbances which, however, are always closely connected with morbid changes in the cortical activity), the study of pathological disturbances of the cortical functions and finally, the study of pathological disorders in the interaction of the cortex with the lower parts of the nervous system (i.e., with the afferent systems of the brain stem and efferent systems of the motor-co-ordinating and vegetative-metabolic centres).

It should be pointed out in advance that no cortical or subcortical affection ever remains absolutely isolated;

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* I. P. Pavlov, *Twenty Years of Objective Study of the Higher Nervous Activity (Behaviour) of Animals*, 6th ed., 1938, p. 492. (Hereafter this work is referred to as *Twenty Years of Objective Study*.)

on the contrary, it has a more or less pronounced and durable dynamic effect on the different parts and functional systems of the brain.

Having begun his research in the pathology of the higher parts of the central nervous system with the study of disturbances of brain activity experimentally induced in animals, Pavlov subsequently extended his investigations to clinical medicine: he subjected a number of human nervous and neuropsychical diseases to a patho-physiological analysis.

Pavlov's ideas of nervism have found here a new, vast field of application and further successful development, which steadily brings them into closer contact with practical medicine. It is noteworthy that even when he was working in the field of the physiology of the higher nervous activity in animals, Pavlov never lost sight of this work being closely related to medicine. For instance, in one of his early works (1906) he stated: "In their fundamental sense physiology and medicine are inseparable. If the physician is actually, and still more in ideal, an engineer of the human organism, then inevitably every new physiological discovery must, sooner or later, increase the physician's power over this extraordinary mechanism, his power to maintain and repair it."* Such a clearly worded tendency not only to investigate phenomena, but at the same time to learn how to govern them, was repeatedly, and at times even more vividly, expressed in Pavlov's subsequent statements.

"Already for many years the physiologist has persistently and systematically investigated, according to the strict rules of scientific thought, the animal organism. He has observed the vital phenomena which appear before him in time and space, and has endeavoured by means of experiments to define the constant and elementary con-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 78.

ditions of their existence and course. His predictions and his control of vital phenomena increase steadily, just as the control of science over inanimate nature increases" (1909).*

"The physiology of the animal brain should not for a single moment leave the ground of natural science which every day proves its absolute solidity and unlimited productiveness. One may rest assured that along this path, upon which the strict physiology of the animal brain has set out, astonishing and marvellous discoveries await science, and that there will result such extraordinary power over the higher nervous activity as is in nowise inferior to the other achievements of natural science" (1914).**

A year later (1915)*** Pavlov, touching on the general conditions of the active and passive states of the cerebral cortex, pointed out that a full analysis of these conditions would probably result in "tremendous power" over the nervous system and "find an extensive practical application."

Much later and nearer to our time Pavlov, in his work *Experimental Pathology of the Higher Nervous Activity* (1935), gave an account of experiments performed by his laboratory, in the course of which it was possible by definite methods to induce definite morbid states of brain activity in animals; he wrote: "The power of our knowledge over the nervous system will, of course, appear to much greater advantage if we learn not only to injure the nervous system but also to restore it at will. It will then have been really proved that we have mastered the processes and are controlling them. Indeed, this is so. In many cases we are not only causing disease, but are

* *Ibid.*, p. 111.
** *Ibid.*, pp. 291-92.
*** *Ibid.*, p. 301.

eliminating it with great exactitude, one might say, to order."*

And finally in one of his last works Pavlov stated: "The most convincing proof that the study of conditioned reflexes has brought the investigation of the higher part of the brain to the right trail ... is provided by further experiments on animals in the field of conditioned reflexes, which reproduce pathological states of the human nervous system—neuroses and separate psychotic symptoms—and which at the same time often secure a rational, deliberate return to normal, a recovery, i.e., a truly scientific mastery of the subject" (1935).**

Thus, as we see, Pavlov invariably combined the study of morbid changes in the functions of the brain with the endeavour to control them, i.e., to remake or eliminate them, "to restore them at will," and thus to secure recovery. In other words, his research in the field of the patho-physiology of the higher parts of the central nervous system was indissolubly bound up with endeavours to originate a therapy that would proceed from an understanding of the causes and origin of the nervous mechanisms and patho-physiological peculiarities of morbid processes, i.e., an experimentally tested therapy based on pathogenesis.

Naturally, the pathology of the higher nervous activity is of prime importance for those branches of medical science, which deal with the study, treatment and prevention of various affections of the brain, neuropsychical diseases, neuroses and psychoses, i.e., for neuropathology, psychiatry, as well as the hygiene of the nervous system.

However, the closest, mutual connection (afferent and efferent) of the higher parts of the central nervous system with the internal medium of the organism (with the

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 690.

** *Ibid.*, pp. 722-23.

vegetative nervous system, the internal organs and cavities of the body, the endocrine apparatus, and consequently, with the vegetative functions and metabolism), brings the patho-physiology of the brain, especially of its higher parts, into closer contact with other branches of medical science and, in particular, with the theory of internal diseases, pediatrics, surgery, gynaecology, oto-laryngology, etc.

As is known, the so-called psycho-somatic trend has recently become widespread in foreign medicine; this trend strives to establish close connection between the mental and the somatic, but in reality it draws a line between them and bases itself mainly on the idealistic psycho-analytical concepts of Freud and other adherents of psycho-analysis.

Here one cannot but recall Pavlov's statement: "If we are to have a truly scientific understanding of our neuropathological symptoms and be able to treat them successfully, we must get rid of the habit so deeply ingrained in us of drawing a line between the mental and the somatic. It is always necessary to proceed from the physiological foundation both in respect of morbific agents and reactions to them with all their consequences" (1935).*

Some Soviet scientists (mostly psychiatrists) have also yielded to the uncritical passion for the psycho-somatic concept and have simply made a muddle of different problems relating to "psycho-somatic disorders."

Regarding the mental as a function of the brain, one must admit that the problem of psycho-somatic relations is, in essence, a problem of interrelations between the activity of the brain and all somatic and vegetative-visceral functions,** or, in other words, physiological

* *Ibid.*, p. 739.

** Whereas previously science distinguished between animal and vegetative functions, now it more often distinguishes between somatic and vegetative functions.

processes developing in the internal medium of the organism.

Consequently, it would be more correct to speak of an encephalo-somatic problem, or even of a broader problem of neuro-somatic relations, implying under the somatic not only the skeleto-muscular functions, but also physiological processes developing inside the soma, i.e., in the internal medium of the organism, and having a vegetative-visceral character. In many cases it is a question of the interaction between the cortex and the vegetative nervous system, between the higher nervous activity and the vegetative nervous activity.

"The problem of psycho-somatic or neuro-somatic relations" is not new to Russian science; the history of its development, as to the original methods and depth of investigation, is one of the most brilliant achievements of Russian physiology and medicine.

The problem of interrelations between the mental and the physiological, already prominently featured in I. M. Sechenov's works, which, as we know, greatly influenced the scientific world outlook of Pavlov, was further developed and brought into closer contact with medical practice by the scientific teachings of S. P. Botkin and I. P. Pavlov, in the idea of the so-called *nervism*; it found clearest expression in the works of the Pavlov school, mainly in the field of the patho-physiology of the higher nervous activity.

In a comment on his M.D. thesis (1883) Pavlov wrote: "Under nervism I imply a physiological trend, which strives to extend the influence of the nervous system to the largest possible number of the organism's activities."*

In the same M.D. thesis he wrote: "I was surrounded by the clinical ideas of Professor Botkin—and I acknowl-

* I. P. Pavlov, *Complete Works*, Vol. I, Academy of Sciences of the U.S.S.R., 1940, p. 142.

edge with heartfelt gratitude the fruitful influence on this work, and on my physiological views in general, of that profound and broad theory of nervism, one that has often anticipated experimental data, which, in my opinion, is Sergei Petrovich Botkin's great contribution to physiology."*

The idea of nervism was steadily developed in Pavlov's works. Already present in his first works on blood circulation, this idea culminated in his theory of the higher nervous activity.

As far back as 1903, in his first work devoted to the theory of conditioned reflexes, then just coming into being, Pavlov declared his intention to build an "experimental psycho-pathology" based on the study of animals. But reality has considerably extended the boundaries of this initial task. Throughout the subsequent thirty-three years, up to his death, Pavlov and his laboratories, and since 1931 also special clinics, organized in accordance with his wishes, unceasingly accumulated and generalized the valuable experimental and clinical data which constituted the backbone of the pathology of the higher nervous activity and laid the foundation for the patho-physiology of the higher parts of the central nervous system.

The work of Pavlov and his school in this direction passed through the following three successive and partly coinciding stages:

1) The experimental study of pathological states of the higher parts of the brain caused by its artificial (surgical) lesion;

2) The experimental study of artificially induced functional disturbances of the higher nervous activity in animals (experimental neuroses);

3) Investigations in the field of the clinical patho-physiology of the higher nervous activity.

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* *Ibid.*

ESSAY I

PATHOLOGICAL CHANGES IN THE HIGHER NERVOUS ACTIVITY, CAUSED BY EXPERIMENTAL LESIONS (EXTIRPATION) OF THE CEREBRAL HEMISPHERES IN ANIMALS

1

FROM EXPERIMENTAL PSYCHO-PATHOLOGY BASED ON THE STUDY OF ANIMALS TO THE PATHO-PHYSIOLOGY OF THE HIGHER NERVOUS ACTIVITY

In his first work (1903), devoted to a strictly objective study of the nervous phenomena developing in the cerebral cortex and underlying the correlations between the organism and the external environment, Pavlov wrote: "After the establishment, possible analysis and systematization of our phenomena, we have come to the next phase of the work—the systematic division and disturbance of the central nervous system in order to see how the previously established relations will be changed. In this way will occur the anatomical analysis of the mechanism of these relations. This will constitute the future and, I am sure, the not far distant experimental psycho-pathology."*

Pavlov was not satisfied with the old theory of the localization of functions which attempted to seek in the cerebral cortex centres for sensations, or sensory centres, for voluntary movements, association, memory, and even for the formation of general ideas (the "highest psychical centres"), a theory which in a preconceived way proceeded from the psychological system of concepts; Pavlov strove to create a theory of the localization of

I. P. Pavlov, *Twenty Years of Objective Study*, p. 34.

functions based on new, neurophysiological principles, on the principles of a strictly objective study of the higher nervous activity.

He was interested in the problem of the significance of various parts of the brain, and of various areas of the cerebral hemispheres for the formation of certain conditioned and unconditioned connections reflecting acquired and hereditary connections between the organism and the surrounding medium. He was also interested in the problem of the dynamic topography of various nervous processes taking place in the cerebral cortex and in the subcortical regions, the problem of the dynamic localization of the phenomena of nervous analysis and synthesis, ranging from their simplest, elementary forms, to the most complex and highest forms.

For this purpose Pavlov, jointly with his collaborators, worked out an absolutely new and original method of combined study which unites the old physiological method of extirpation, i.e., of surgical removal or destruction of various parts of the brain, with the strictly objective method of studying the higher nervous activity created in his laboratory, i.e., the method of investigating conditioned and unconditioned reflexes.

Previously the physiologist, upon removing a part of the cerebrum, considered the disturbances induced in the behaviour of the animal from a psychological viewpoint, and regarded these disturbances as a result of the lesion or removal of the material, morphological substratum of a certain psychical function (sensation, idea, voluntary movement, etc.); but now, observing similar "psychopathological changes" artificially induced in the behaviour of the animal, Pavlov regarded them primarily as disturbances of adaptation of a living organism to the external environment. He viewed them as disturbances of connections, correlations between the brain and the surrounding medium, disturbances of the course and interaction of

nervous processes in the higher parts of the central nervous system, evoked by the extirpation of one or another part of the cerebrum, i.e., by surgical intervention.

Proceeding from this new scientific point of view, Pavlov intended to build an "experimental psycho-pathology based on the study of animals."

"Certainly," he wrote, "psycho-pathological experiments had their beginning at the time when the physiologists first removed a part of the central nervous system, and observed the animals that survived the operations. . . . We already know the definite limitations of the adaptive capacity of animals having the cerebral hemispheres or a part of them removed. But the investigation of this theme has not yet formed a special branch, the study of which could proceed without interruption according to a definite plan. The cause of this lies, I think, in the fact that the investigators do not possess at present any considerable and detailed knowledge of the normal relations of the animal to its surroundings, with the help of which they might make an exact and objective comparison of the state of the animal before and after operation. . . . We can analyse adaptability in its simplest form by use of objective facts. What reason is there to change this method in studying adaptability in the higher orders!"*

Whereas the old theory of the localization of functions regarded the pathological disturbances in the behaviour of the animal evoked by extirpation from the psychological and, moreover, anthropomorphical point of view, and tried to establish psycho-anatomical correlations of a highly speculative character, Pavlov set himself an altogether different and absolutely new research target.

Combining the method of extirpation with the method of conditioned reflexes, he strove to establish connections between the morphology of the brain and the physiology

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 35.

of the higher nervous activity created by him, i.e., to establish correlations between physiology and anatomy in this field.

In one of his works (1932) Pavlov, touching on the history of the theory of localization of functions in the brain, wrote: "For a long time the situation remained uncertain, because the physiologist did not have purely physiological knowledge of the normal activity of the cortex; the use of psychological concepts, when psychology has not yet created a natural and generally accepted system of its phenomena, could not of course be conducive to the further study of the problem of localization. The situation radically changed when, thanks to the theory of conditioned reflexes, the physiologist was at last provided with the possibility of seeing the special, and at the same time purely physiological activity of the cerebral hemispheres and thus could clearly distinguish the physiological activity of the cortex from the activity of the nearest subcortex, and the lower parts of the brain in general, in the shape of conditioned and unconditioned reflexes. Then all the separate facts could be definitely and strictly systematized, and the main principle of the structure of the cerebral hemispheres came clearly to the fore."*

Pavlov's attention was focussed on the question of how to impose the pattern of the highest nervous processes, their course and interaction, their synthesis and analysis on the morphological canvas, how to study the laws of the fluctuations and changes in the spread of these processes over the brain tissue, how to perceive the functional significance and role of the different parts of the brain in that "most complex dynamic system, continuously tending to integration," which is presented by the cerebral cortex.

I. P. Pavlov, *Twenty Years of Objective Study*, pp. 550-51.

But laying the foundation for a new, neuro-dynamic theory of the localization of functions, Pavlov simultaneously began to elaborate the experimental pathology of the higher nervous activity, the patho-physiology of the higher parts of the central nervous system.

However, before dealing with the experimentally induced pathological states described by Pavlov in the course of investigating the activity of the brain by the combined method of extirpation and conditioned reflexes, we shall dwell upon the peculiarities of the localization of functions in the brain disclosed by the founder of the theory of conditioned reflexes as a result of many years of experimental study of the higher parts of the nervous system.

2

THE MAIN FEATURES OF THE ACTIVITY OF THE CEREBRAL HEMISPHERES

Already in the basic concepts of Pavlov's theory we find the major biological problems expressed with extreme brevity and with an amazing depth of synthesis: the interaction between the organism and its environment, heredity, acquired experience, adaptability, the inheritance of acquired characteristics, the ontogenic and philogenic development.

The cerebral hemispheres, the cerebral cortex of the higher animals present an organ for the finest and most complex equilibration (adaptation) of the organism in its environment; it is an organ coupling new *conditioned connections* between the organism and the external environment and preserving the old ones, previously formed, temporary, variable, acquired in the course of the ontogenesis and depending upon a multitude of conditions; it is an organ which dynamically reflects and imprints the

whole life of the animal, all the conditions of its ontogenic development. Through it the organism is warned against and prepared for all the changes in the external environment approaching in space and time; it effects the signalization, now stimulating the organism to a certain activity, now inhibiting it (which is, according to Pavlov, the signalling activity of the cortex).

"The infinite fluctuations in both the outer and inner mediums of the organism, each of which is reflected in definite states of the nervous cells of the cerebral cortex may become separate conditioned stimuli,"* i.e., may establish a temporary, acquired ontogenic connection with one or another activity of the organism.

"From this point of view the physiological role of the cerebral cortex is, on the one hand, a coupling function (according to the mechanism) and on the other hand, a signalling function (according to its significance), and the signalization is variable in strict correspondence with the external conditions."**

Continuous analysis and synthesis of conditioned connections takes place in the cerebral cortex in the course of the ontogenic development.

"But the detailed highest analysis and synthesis effected by the cerebral hemispheres are not confined to the external environment only. The internal medium of the organism, its organic changes are subjected to similar analysis and synthesis, particularly and most of all, the phenomena which develop in the skeleto-muscular system, i.e., the tension of separate muscles and their innumerable combinations and its duration. These finest elements and moments of skeleto-muscular activity are stimulations similar to those coming from external receptors, i.e., they can establish temporary connections both with the activ-

* I. P. Pavlov, *Lectures*, p. 48.

** I. P. Pavlov, *Twenty Years of Objective Study*, p. 436.

ity of the skeletal musculature itself and with all other functions of the organism. This provides the diverse and finest adaptation of the skeleto-muscular activity to the conditions of the surrounding, permanently fluctuating medium. . . . This mechanism effects our slightest movements acquired by elaboration, such as the movements of the hands. This also relates to speech movements."*

Quite a different function is performed by the lower parts of the central nervous system—by the subcortical ganglia, the brain stem and the spinal cord; they effect permanent hereditary connections between the organism and its environment formed in the course of the philogenesis, and relatively little subject to changes (as compared with cortical connections), i.e., *unconditioned connections.*

Thus, here it is a question of the localization of the hereditarily determined activity of the somatic and vegetative nervous system. Instincts are the highest synthetic forms of this unconditioned reflex activity. Consequently, the lower parts of the central nervous system in higher animals preserve and effect the philogenic experience imprinted in these parts and set in motion by various unconditioned stimuli which are hereditarily connected with somatic and vegetative reactions. These stimuli may come both from the external and internal medium of the organism.

"One may assume," Pavlov said (1913), "that some of the conditioned, newly acquired reflexes are subsequently, through inheritance, transformed into unconditioned reflexes."**

In an article written by Pavlov one year later (1914), we read the following: "It is highly probable (and we already possess some data to this effect) that newly formed

* *Ibid.*, p. 491.
** *Ibid.*, p. 275.

reflexes, given the same conditions of life for a number of successive generations, incessantly pass over into constant reflexes. This must be one of the acting mechanisms in the evolution of the animal organism."*

Taking a definitely monistic stand in respect to inhibitory processes in the central nervous system, Pavlov first subdivided them into external, internal and general sleep inhibitions. But during the last years of his life he distinguished between unconditioned, or passive, and conditioned, or active, inhibitions (each of which may under certain conditions pass over into sleep).

In the first category Pavlov included 1) the inhibition which usually develops at the periphery of the process of nervous excitation, as if edging it, and which furthermore, follows after the excitation is over; this kind of inhibition was called simultaneous and consecutive negative induction; 2) the inhibition which is evoked when there are two or more competing stimuli and which in essence is a particular case of negative induction; this inhibition was previously called external inhibition, and 3) the inhibition which is observed in the nerve cells under the action of the strong, unduly prolonged and other noxious conditioned and unconditioned stimuli, exceeding the working capacity of the nerve cells, i.e., transmarginal inhibition; similar phenomena developing mainly under pathological conditions were also often termed by Pavlov protective inhibition.

Under conditioned or active inhibition, which previously had been called internal inhibition, Pavlov included all kinds of inhibition acquired and elaborated during life, i.e., inhibitory connections (differentiation, retardation, extinction, and conditioned inhibition—in the narrow sense of the word).

All kinds of inhibition (like the phenomena of excita-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 283.

tion) may develop now in a more concentrated, now in a more irradiated form.

The phenomena of unconditioned, passive inhibition are, according to Pavlov, inherent in all parts of the central nervous system without exception, but the phenomena of conditioned, active inhibition are inherent only in its higher part—the cortex. Thus, from the evolutionary aspect unconditioned, passive inhibition is older than conditioned, active inhibition.

Under a strongly pronounced irradiation of both passive and active inhibitions they pass over into general sleep inhibition spreading over the cortex and extending to the lower parts of the brain.

As we see, Pavlov's views on the origin and localization of functions in the central nervous system are of a distinctly evolutionary character, which finds expression already in the basic concepts of the theory of the higher nervous activity.

All that has been said concerning the origin and localization of conditioned connections relates mainly to the higher animals—since in the lower vertebrates the function of establishing new connections appears to be also to a certain degree inherent in the brain stem, at least in its higher parts.

In 1912-1913 the basic, most important functions of the cerebral hemispheres appeared to Pavlov "as the expression of two chief mechanisms: the mechanism of the formation of temporary connections between the agents of the external world and the action of the organism, i.e., the mechanism of the conditioned reflexes ... and the mechanism of the analysers, i.e., an apparatus whose purpose it is to analyse the complexity of the external world, to decompose it into its separate elements and moments."* At that time Pavlov already expressed the view

* *Ibid.*, p. 208.

that there are special analysers in the cortex relating to the internal medium of the organism. "Thus, the cerebral hemispheres," he said, "according to our understanding of the matter, consist of a number of analysers: of the eye, ear, skin, nose and mouth analysers. An examination of these analysers brought us to the conclusion that their number must be greater, that besides the above cited ones relating to external phenomena, to the outer world, there must be recognized in the cerebrum special analysers, whose purpose it is to decompose the enormous complexity of inner phenomena which arise within the organism itself. There is no doubt that not only is an analysis of the external world important for the organism, of equal value is the signalling upwards and analysis of everything taking place within the organism itself. In short, besides the external analysers there must be internal analysers. The most important of these internal analysers is the analyser of movements, the motor analyser."*

Mainly on the basis of experiments performed by N. I. Krasnogorsky (1911), Pavlov came to the conclusion that the so-called motor region of the cortex is an analyser of kinesthetic, proprioceptive stimuli, i.e., stimuli coming from the skeletal muscles, tendons and joints, in other words, it is the motor analyser.

"One must now add to the generally known analysers —eye, ear, skin, nose and mouth—the analyser of movements which has to do with centripetal stimulations coming from the motor apparatus itself, from the muscles, bones, etc. Consequently, to these five external analysers we must add a highly delicate analyser—the internal analyser of the motor apparatus, which signalizes in the central nervous system every moment of the given movement, the position and tension of all parts engaged in the movement. For this analyser there is a special place in

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 210-11.

the cerebral hemispheres, and this place is the motor region of the cerebral hemispheres."*

In one of his last works (1935) Pavlov wrote: "In the physiological laboratory of the Military Medical Academy Krasnogorsky (1911) definitely established the undoubtedly afferent nature of the motor region of the cortex by forming from the kinesthetic stimulation of the skeletal musculature a conditioned food stimulus just as it is formed from all other stimulations entering the cortex through the external receptors—the eye, the ear, etc."**

However, it would be erroneous to think that Pavlov placed on a par and regarded as equivalent the study of the activity of the brain connected with the external environment, and the study of its activity relating to the internal medium of the organism.

Concerning the prospects for the development of his theory of the higher nervous activity, Pavlov wrote: "I dare to think that the following account will convince you, even as I am convinced, that in the given case there opens before us an unlimited province for successful research, the second immense part of the physiology of the nervous system as a system which mainly establishes the relation not between the individual parts of the organism, with which we previously dealt, but between the organism and the surrounding world."***

Thus, already in the first "Summary of results of the removal of different parts of the cerebral hemispheres by the method of conditioned reflexes" (1912-1913) Pavlov came to the conclusion that "the cerebral hemispheres represent a combination of analysers, which decompose the complexity of the external and internal worlds into

* *Ibid.*, pp. 174-75.
** *Ibid.*, p. 701.
*** *Ibid.*, pp. 24-25.

individual elements and moments and afterwards connect the phenomena thus analysed with the special activities of the organism."* In other words, it turns out that the cerebral cortex produces not only phenomena of analysis, but along with them and in close connection with them also phenomena of synthesis.

At subsequent stages of investigation Pavlov devoted more and more attention to the problems of cortical synthesis. For example, in 1927 he stated: "The mechanism and localization of the *synthesizing* activity of the nervous system, as compared with its analysing activity, are little known up to the present. The simplest way is to assume that they are connections between the nerve cells, no matter whether they are intercellular membranes or simply fine ramifications with their inherent properties. Of course, our immediate task must consist in accumulating experimental material concerning the synthesizing activity."**

In his study of the complex functional system, which is presented by the cerebral cortex, Pavlov attached great importance to the synthesizing activity; this may be seen from the following statement made by him in 1930: "From the standpoint of the physiologist the cerebral cortex is simultaneously and constantly fulfilling both analytical and synthetical functions, and any discrimination between the two, any study of one in preference to the other will not lead to real success, to a complete understanding of the work of the cerebral hemispheres. Just as analysis and synthesis serve in the hands of the chemist as powerful means of studying the structure of an unknown chemical compound and of explaining all its properties, the analysis and synthesis of the nervous processes provide the physiologist with a most reliable key to the understand-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 222.

** I. P. Pavlov, *Lectures*, pp. 124-25.

ing of the complex functional structure of the cerebral hemispheres."*

From this it follows that the analysers described by Pavlov are essentially synthesis-analysers, since they effect not only the reception and differentiation of stimuli entering the cortex, but also their connection, their association with each other and with various activities of the organism, i.e., phenomena of cortical synthesis, or cortical integration. Describing such facts, Pavlov stated: "Thus, here we have a phenomenon of nervous synthesis, a coupling function of the cerebral hemispheres which complexly directs the entire activity of the organism."**

Pavlov repeatedly returned to the question of the localization of this function in the cortex. He said: "Probably the site of this coupling activity should be sought in the points of union of the neuroses (especially, in the cortex)."***

In another work he stated: "The coupling, the formation of new connections we attribute to the functions of the intercellular membrane, if it exists, or simply to the fine ramifications between the neurones, between the separate nerve cells. The fluctuation of excitability, the transition into inhibition we attribute to the very cells themselves. This distribution of functions appears to us probable in the light of the fact that while the new well-elaborated connections are preserved for a long period, the alteration of the excitability, the transition into inhibition are highly vacillating phenomena. The processes of excitation and inhibition appear to us to be different phases in the activity of the cortical cells of the cerebral hemi-

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* I. P. Pavlov, *The Physiology and Pathology of the Higher Nervous Activity*, State Medical Publishing House, 1930, p. 36.

** *Ibid.*, pp. 8-9.

*** I. P. Pavlov, *Twenty Years of Objective Study*, p. 365.

spheres. We assert that these cells possess a high degree of reactivity and, consequently, destructibility."*

Thus, in Pavlov's view, the whole of the cerebral cortex is an entire receptor surface consisting of a number of receiving areas (analysers, or to be more exact, synthesis-analysers), each of which is a projection of certain peripheral receptors (cutaneous, kinesthetic, visceral receptors), or of a certain sense organ (taste, smell, sight, hearing).

Each of these areas has its central part, or nucleus, which effects the highest synthesis and analysis, and its periphery widely spread over the cerebral cortex, where synthesis and analysis are possible only in the most elementary forms. The peripheral parts of different areas are entwined and intermingled. Consequently, in the cerebral cortex there are, on the one hand, regions performing specific and highly developed functions (the nuclei of the analysers), and on the other hand, regions located in the intervals and filling them; here are the nerve cells belonging to different analysers and capable only of elementary synthesis and analysis.

As to the coupling function, according to Pavlov, it has no definite localization; a temporary, acquired, conditioned connection, or, in other words, an association, may arise between various points of the cerebral cortex; it may connect, combine different cortical areas. Any stimulation reaching the cerebral cortex may develop a conditioned connection, may associate with any activity of the organism.

Hence it is clear that Pavlov denied the existence of special centres or areas for association in the cerebral cortex; he considered that associative or combinative activity is inherent in the whole of the cerebral cortex. Nor did he admit the existence of special "mnestic centres."

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 444.

"The connection arising in the cerebral hemispheres," he said, "is probably due to their extreme reactivity and ability to impress, and constitutes a permanent and characteristic property of that part of the central nervous system."* Rejecting the existence of association centres, Pavlov at the same time did not agree with those who attempted to locate in the cerebral cortex (mainly in the frontal lobes) special "highest centres" governing the whole cortical activity. "Our experimental facts," he wrote, "most emphatically refute the doctrine of special association centres, or more generally, of the existence in the hemispheres of a special area performing supreme nervous functions, a doctrine which has already been opposed by H. Munk."**

3

PAVLOV'S BASIC VIEWS ON THE LOCALIZATION OF FUNCTIONS IN THE HIGHER PARTS OF THE CENTRAL NERVOUS SYSTEM

And so, for Pavlov, the whole surface of the cerebrum, the whole of the cerebral cortex, is the seat of a signalling and coupling, sensory-associative, receptory-combinative function, in the course of which the phenomena of cortical synthesis and analysis are developed.

However, the question may naturally arise, what were Pavlov's views on the motor functions, or, in a broader sense, the effector functions of the cerebral cortex.

While not denying that the cerebral cortex, and in the first place, its lower layers (mainly, the fifth or sixth, and particularly, the region of the gigantic pyramids) origi-

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* *Ibid.*, p. 606.

** I. P. Pavlov, *Lectures*, p. 327.

nate an enormous quantity of efferent fibres, Pavlov regarded them first of all as paths connecting the cortex with the subcortical ganglia, with the nuclei of the motor and secretory cranio-cerebral nerves, with the anterior horns of the spinal cord. At the same time he was inclined to consider these efferent neurones not so much as executive, working, effector ones, but rather as internuncial neurones, linking, connecting the cortex with the effector neurones proper, originating in the nuclei of the cranio-cerebral nerves and the anterior horns of the spinal cord.

"Thus," Pavlov said in 1923, "the cortex is only a receptor apparatus, which in various ways analyses and synthesizes the incoming stimulations. These stimulations reach the real effector apparatus only by means of descending connecting fibres."*

Consequently, Pavlov was inclined to regard the cortical efferent neurones mainly as vehicles of regulatory and co-ordinating functions in relation to the activity of the lower levels of the central nervous system.

Let us try now to sum up Pavlov's basic conceptions of the localization of functions in the cerebral cortex.

1. The whole cerebral cortex is "a complex of analysers" (or, to be more exact, of synthesis-analysers), i.e., the receiving surface of the cerebral hemispheres, where, on the one hand, the analysis and synthesis of external and internal stimuli are effected, and, on the other hand, their coupling, connection, association with each other and with the various functions of the organism.

2. Besides analysers reflecting the external environment, in the cerebral cortex there are also analysers reflecting the internal medium of the organism.

3. The so-called motor region in its turn performs the function of reception, analysis and synthesis of stimuli

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 370.

coming into the cortex from the skeletal muscles, joints and tendons, i.e., kinesthetic, proprioceptive stimuli.

"The motor region," Pavlov said, "is an analyser of the locomotor energy of the skeletal muscles, exactly as other regions are analysers of different kinds of energy acting on the organism from the outside. From this point of view the cerebral hemispheres represent a huge analyser of the external as well as of the internal medium of the organism. Obviously, if one accepts this hypothesis in relation to the motor activity of the skeletal muscles, there is good reason to extend it to most of the organism's activities, if not to all of them."*

4. Each analyser has its central part (nucleus), which effects the complex, highest forms of analysis and synthesis, and its periphery where analysis and synthesis are possible only in the most elementary forms. There are no precise and definite boundaries between the analysers which at the periphery gradually pass into the peripheral zones of the adjacent analysers.

Thus, according to Pavlov's concepts, in the cortex between the nuclei of different analysers there are regions containing dispersed and, so to say, intermingled nervous elements, which belong to diverse analysers and which under usual conditions are only capable of performing the most elementary functions (perhaps it would not be erroneous to assume that here are located cortical elements considerably less differentiated in respect of their functions and less reactive than those in the central parts of the analysers).

5. The coupling, combinative, associative function is performed by the whole of the cerebral cortex. As stated

* I. P. Pavlov, *Lectures*, pp. 311-12. As is known, these concepts of I. P. Pavlov were corroborated and further developed by the extensive experimental work conducted by K. M. Bykov and his school.

above, the existence of special association areas, or centres, in the cerebral hemispheres, is denied by Pavlov.

6. The function of impressing the stimuli entering the cortex and the connections formed in it is not confined to any special centres (which are called "mnestic centres" by certain foreign authors), but is inherent in the whole of the cerebral cortex.

7. No special part or "centre" performing a supreme nervous function exists in the cerebral hemispheres.

It should be stressed again that whereas the old theory of localization of functions was based on the idea of psycho-morphological correlations, in the endeavour to find an anatomical substratum for each psychological, or psycho-pathological phenomenon, Pavlov's conceptions of localization are characterized by physiologico-morphological correlations. No matter whether the cerebral hemispheres in dogs were completely removed, or only certain parts of them were extirpated, Pavlov invariably and in every possible way avoided interpreting the resulting disturbances from a psychological point of view; he always strove to study the disturbances of the neurophysiological functions, the derangements in the dynamics of the higher nervous processes, which resulted from the experimental lesion of the cerebrum and which evoked certain pathological changes in the behaviour of the animals subjected to the operation.

For example, describing the experimental results, which were obtained in dogs after the extirpation of the temporal lobes, Pavlov said: "The described absence or diminished precision of the analysing function of the acoustic nervous apparatus is obviously identical with what H. Munk originally described and termed as 'psychic deafness.' It is impossible, however, not to see the fundamental difference between the psychological and purely physiological interpretation of that fact. According to Munk's definition 'the animal hears but fails to under-

stand,' and experimentation proves sterile when it comes to interpreting 'understand.' No way out is afforded. But the physiological point of view opens up a vast field for experimentally investigating the different stages of the re-establishment of an impaired function in the acoustic analyser. Under normal conditions sounds are differentiated according to their general properties—strength, duration, continuous or interrupted character, point of origin, and according to their purely acoustic properties—knocks, tones, etc. It must be expected—and, as mentioned above, we already have definite facts proving this—that in returning to normal the damaged acoustic analyser passes through different stages of activity, and the investigation of these stages can provide a key to a better understanding of the mechanism of acoustic analysis."*

Indeed, a dog with extirpated temporal lobes pricked its ears at any sound, and in particular, at any word uttered by its master, but did not respond to its name and did not react to various orders, as was the case before the operation. According to Munk, the dog "heard but failed to understand" (psychic deafness); however, according to Pavlov, the dog was deprived of the ability to synthesize and analyse complex acoustic stimuli, to which various motor conditioned reactions had been elaborated before the operation in the course of training, reactions that disappeared after the removal of the "nucleus" of the acoustic synthesis-analyser.

While Munk's definition "hears but fails to understand" and to a greater degree his term "psychic deafness" actually did not explain anything at all, but merely described the facts, Pavlov's explanations revealed the significance of the bilateral extirpation of the temporal lobes of the hemispheres for the development of higher nervous processes in the cerebral tissue, i.e., in space and

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* I. P. Pavlov, *Lectures*, pp. 291-92.

time; they disclosed the nature of the disturbances of these processes and thus established close connection between the localization of the lesion and the character of pathological changes evoked by it in the activity of the cerebrum.

In a similar way Pavlov explained the disturbances which were evoked by the extirpation of the central part of the visual analyser.

The phenomena of "psychic blindness" (optical agnosia), as Munk termed them, were regarded by Pavlov as loss of ability to synthesize and analyse complex visual stimuli.

Investigating the disturbances evoked by the lesion of the motor analyser, Pavlov similarly rejected all psychological or patho-psychological explanations in this respect. He said: "The general locomotor activity, which is effected by the subcortical parts of the brain definitely remained unaffected, while the precise and delicate activity of the skeletal muscles, at any rate of some of them, which is determined by conditioned reflexes, had disappeared."*

The following three principles underlie Pavlov's concepts of localization:

1) The principle of determinism in accordance with which Pavlov, as previously Sechenov, saw in each process developing in the cerebral cortex a synthesis of three components—reception, connection and effect (positive or inhibitory); in other words, each such process must necessarily be originated by an initial cause in the external or internal medium of the organism, a cause now more immediate, now more remote.

2) The principle of analysis and synthesis which extends to all nervous processes taking place in the brain.

3) The structural or systemic principle, i.e., the prin-

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* I. P. Pavlov, *Lectures*, p. 315.

ciple of "adjusting the dynamics to the structure" (Pavlov); the localization of nervous processes in the various structures and systems of the cerebrum; the establishment of correlations between the structure of the higher parts of the central nervous apparatus and their functions; the dynamics of the distribution of functions in the structures and systems of the cerebrum.

In one of his first works devoted to conditioned reflexes (1904) Pavlov wrote: "New reflexes are the function of the highest structures of the nervous system of the animal, and they must be regarded as such on the following basis. First, they represent the most complicated phenomena among nervous functions and, naturally, must be connected with the highest parts of the nervous system."*

Six-seven years later Pavlov became interested in the structure of the food centre. He wrote: "It must be said that physiologists consider the question of topography more indifferently than pathologists do. For physiologists the question of the function and of the activity of the centre is of greater importance. That the exact location of the centre is not an easy matter may be seen from the example of the respiratory centre. At first one thought that this centre was in the medulla oblongata and about the size of a pin-head. But at present its limits have greatly broadened, it has ascended into the brain and descended into the spinal cord, and now no one can exactly define its boundaries. In the same way, one must assume that the food centre is widely spread out in the central nervous system.... We must admit that the food centre is situated at various levels of the central nervous system.... The food centre must consist of scattered cell groups, and there must be an especially large group of such cells in the hemispheres."**

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 52.

** *Ibid.*, pp. 155-56.

Thus, in the light of the new physiological concept Pavlov regarded the food centre as a certain functional union, as a functional system.

In 1916 he wrote: "Even now we can still remain within the limits of the earlier concepts of the so-called centres of the central nervous system. We must only add to the earlier exclusively anatomical conceptions the physiological point of view and admit the existence, thanks to certain well-formed paths of connection, of a functional union of various parts of the central nervous system for the performance of certain reflex actions."*

Reverting to the localization of conditioned connections in the brain, Pavlov stated in 1923 that the formation of "functional combinative centres"** corresponds to their coupling. Ten years later he wrote: "With the philogenic development of the central nervous system, the nervous combinative systems, in the shape of definite so-called reflex centres, which become more and more complex, were steadily moving closer to the head end, representing an ever growing analysis and synthesis of stimulating agents in connection with the increasing complexity of the organism and the extension of its relations with wider regions of the external environment.... If so, a highly complex matter must be investigated, the question of connections and of the nature of connections between these different levels."*** Already in 1927 Pavlov defined the cerebral cortex as a "dynamic system" and somewhat later as "a functional structure" (1930). Subsequently, the problem relating to the phenomena of the functional system in the cortex became the object of a number of special experimental investigations (E. A. Asra-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 324.

** *Ibid.*, p. 365.

*** *Ibid.*, p. 523.

tyan, G. V. Skipin, V. V. Rickman, L. O. Seewald and others).

During the last years of his life (1932-1936) Pavlov introduced into the problem of localization of functions, especially in the human brain, a new concept of the first and second signalling systems, to which we shall revert later.

Thus, the theory of the higher nervous activity is fully imbued with the idea of the functional dynamic system or structure, which is also reflected in Pavlov's views on the localization problems.* It must be emphasized that this idea was engendered and developed in a number of works by Pavlov long before certain remotely similar ideas began to be propagated by the adherents of the so-called gestalt, or configuration psychology.

Concerning the two conflicting psychological schools —one that proceeds from the concept of associations (associative psychology) and the other proceeding from "psychical structures" (gestalt psychology), Pavlov said (1930):

"The physiology of the cerebral hemispheres at the present stage of its development makes it possible to combine both concepts on the basis of strict facts. It is absolutely clear to us that the cerebral cortex is a most complicated functional mosaic of separate elements, each of which has a particular physiological function, positive or inhibitory. At the same time it is also quite obvious that at every given moment all these elements are combined into a system, in which each element interacts with all others."**

* Some of Pavlov's disciples attempted, without any justification, to ascribe this idea to themselves.

** I. P. Pavlov, *The Physiology and Pathology of the Higher Nervous Activity*, 1930, pp. 35-36.

It has to be admitted, not without regret, that to this day the originality and novelty of Pavlov's views on the localization of functions in the brain have not been duly recognized and adequately appreciated, even by some (though at present not numerous) representatives of Russian science.

4

GENERAL AND LOCAL DISTURBANCES OF THE WORK OF THE BRAIN RESULTING FROM INJURY TO VARIOUS PARTS OF THE CEREBRAL HEMISPHERES

In 1927 Pavlov said: "Having obtained a sufficient and quite objective idea of the activity of the cerebral hemispheres, we naturally became interested in making a thorough study of the constitution of the cerebral hemispheres and the functions of their individual parts as planned by us at the very outset of our experimental work."*

A particularly great deal of experimentation on these problems was done in Pavlov's laboratories in the period 1906-1913 (N. P. Tikhomirov, L. A. Orbeli, M. I. Eliasson, N. K. Toropov, V. A. Demidov, G. P. Zeliony, N. I. Krasnogorsky and others). A marked revival of research in this field has been also observed since the early twenties (G. P. Zeliony, D. S. Fursikov, I. P. Razenkov, O. S. Rosenthal, I. N. Zhuravlev, E. A. Asratyan, M. N. Yurman and others).

The attention of some research workers was naturally attracted by the problem of disturbances of the nervous activity resulting from the extirpation of both cerebral hemispheres (G. P. Zeliony, E. A. Asratyan, S. I. Lebedinskaya and O. S. Rosenthal).

I. P. Pavlov, *Lectures*, p. 279.

The basic conclusion was that the removal of the entire cerebral cortex results not only in irretrievable loss of the coupling function, i.e., makes impossible the establishment of new, temporary, that is, conditioned, connections, but also irretrievably eliminates the entire individual lifetime experience acquired by the higher animal and impressed in the cerebral cortex in the shape of various conditioned connections. There remains only unconditioned reflex activity, including its most complex forms —the instincts (alimentary, self-defence, sexual, etc.).

Disturbances resulting from the extirpation of only one hemisphere were also the object of experimental investigation (D. S. Fursikov, E. A. Asratyan, K. M. Bykov, M. N. Yurman, O. S. Rosenthal).

Thorough research was carried out in the field of investigating the disturbances in different analysers (motor, cutaneous, visual) after the extirpation of the upper halves of both hemispheres (L. A. Orbeli); after the removal of the posterior parts of the cerebral hemispheres, when the highest synthesis and analysis of the acoustic and optical stimuli suffered most, and when the animal spent most of the time in sleep (N. K. Toropov, A. N. Kudrin and others); and finally, after the extirpation of the anterior halves of both hemispheres, when primarily the highest synthesis and analysis of skin stimuli and motor actions (or to be more precise, kinesthetic stimuli) were impaired and when secondary disturbances of other analysers also took place (V. A. Demidov, N. M. Saturnov, S. P. Kurayev, N. P. Tikhomirov and others).

Numerous experimental investigations were devoted to the special study of disturbances in the activity of the ce ebral hemispheres, caused by the extirpation or partial lesion of the central part (nucleus) of a certain cortical analyser. These are treated in the works of I. S. Makovsky (1908), M. I. Eliasson (1908), I. I. Krizhanovsky (1909), A. N. Kudrin (1910), L. N. Voskresensky (1912)—relat-

ing to the acoustic analyser; the works of N. K. Toropov (1908), L. A. Orbeli (1908), A. N. Kudrin (1910) devoted to the study of the visual analyser; the works of N. P. Tikhomirov (1906), A. A. Shishlo (1910), N. I. Krasnogorsky (1911), L. N. Voskresensky (1912), M. N. Yerofeeva (1921), I. P. Razenkov (1924), I. N. Zhuravlev (1924), K. M. Bykov (1924), D. S. Fursikov (1925), M. N. Yurman (1925) and O. S. Rosenthal (1938) relating to the cutaneous analyser, and finally, the works of N. I. Krasnogorsky (1911), D. S. Fursikov (1926), E. A. Asratyan (1934-1935) and O. S. Rosenthal (1938), who investigated the motor-kinesthetic analyser.

In almost all of these works it was clearly and convincingly shown that when the central part of an analyser is partially damaged, the most complex forms of its synthetical and analytical activity were the first to suffer to a greater or lesser degree (depending on the localization and extent of the damage), and that with the lapse of time the induced defect tends to obliteration, levelling out and restoration of the disturbed functions. When the central part of an analyser (the nucleus) is completely removed on both sides, only the most elementary forms of the cortical synthesis and analysis are restored, or can be obtained anew (at the expense of the periphery of the analysers); as to their most complex, highest forms of synthesis and analysis, generally it proved impossible to restore them or to obtain them in any new modifications.

The localization of the lesion (and to a certain degree, its extent) determined the qualitative nature of the disturbances induced. In some cases, for example, the synthesis and analysis of sounds were disturbed (of different pitch, intensity, timbre, duration, remoteness, etc.); in other cases—those of visual stimuli (different in brightness, colour, form, disposition in space, etc.); sometimes the synthesis and analysis of cutaneous stimuli were

affected, sometimes—those of kinesthetic stimuli, and so forth.*

It must be stressed that the disturbances of the cortical synthesis and analysis always developed simultaneously and were closely interconnected, never appearing separately, never being completely isolated or disunited.

Therefore, certain psychiatrists are absolutely wrong when they regard various complex disturbances of the higher nervous activity in man only as phenomena of disintegration, i.e., of dissociation of synthetic functions, and do not pay attention to the fact that such disturbances are usually closely connected with the phenomena of dedifferentiation as well, with disturbances of the analytical activity of the cerebral cortex.**

Comparing the disturbances experimentally obtained in all the above-described cases of cortical extirpation of different localization and extent, we are able at the same time to establish their common features.

1. To begin with, in all cases there are in evidence disturbances of *reception*; the impression of external and internal stimuli (proprioceptive and interoceptive) in the cerebral cortex is also deranged. The previously mentioned statements of Pavlov concerning the cortical analysers of the "internal medium of the organism," and particularly the valuable investigations of K. M. Bykov and his school, who furnished a number of convincing experimental proofs of the correctness of Pavlov's suppositions in this respect, lead us to the conclusion that injuries

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* Recently L. G. Voronin (of the Institute of Evolutionary Physiology) has shown that the analysis and synthesis of *compound* stimuli become disturbed for a certain period of time, no matter which part of the hemispheres is damaged.

** It must be also pointed out that the terms "disintegration" or "dedifferentiation" by themselves do not explain anything. Each separate case must reveal the actual changes of the higher nervous activity in which they are expressed.

located in different parts of the cerebral cortex (partial lesions or extirpation of considerable sections of the cortex) may result in the disturbance of the cortical reception and analysis not only of the internal stimuli coming from the joints and muscles, but also of visceral stimuli.

2. In all cases of extirpation described by the Pavlov school, irrespective of its localization in the cerebral hemispheres, there were observed *disturbances of the coupling*, connecting, associating function (both in respect of conditioned connections, which existed before the extirpation, and the formation of new connections); consequently, there were disturbances of the synthesis and analysis.

3. In all cases the disturbances of reception, coupling, synthesis and analysis manifested themselves also in the derangement of the organism's activities (motor and secretory) connected with the given reception. Naturally, when the reception of certain stimuli was impossible, the conditioned reactions connected with them also disappeared and could not be evoked. Consequently, the disturbances of reception (and at the same time of the synthesis and analysis of external or internal stimuli) inevitably resulted in *disturbances of the effector activity* (motor and secretory). These disturbances manifested themselves with particular force and in highly diverse forms when the motor-kinesthetic analyser was affected.

The extirpation of different parts of the cerebral hemispheres, as we shall see later, was usually followed by disturbances of the dynamic correlations between the cortex and subcortical regions, between the cerebrum and the brain stem, reflected in various disturbances of the unconditioned reflex activity and of the vegetative functions connected with them.*

* However, it should not be forgotten that in some cases disturbances of vegetative functions could result from the rupture of connections between these functions and their conditioned stimuli, or from the derangement of the reception of these stimuli.

5

VARIOUS STAGES OF DISTURBANCES OF THE CEREBRAL ACTIVITY RESULTING FROM INJURY TO THE CEREBRAL HEMISPHERES

Local disturbances directly resulting from extirpation proved to be overshadowed and disguised for a more or less prolonged period of time by a number of general pathological changes in the higher nervous activity due to surgical intervention.

These general changes consisted, on the one hand, in massive *diffused* disturbances, which reflected the rough surgical trauma of the cerebral tissue (concussion, pressure, strain, haemorrhage, disorders of blood circulation, of intracranial pressure, of lymph circulation, etc.), and, on the other hand, in systemic disturbances which arose in consequence of the extirpation.

Indeed, if we recall Pavlov's concepts of the functional union, functional structure or system, which connects certain groups of cortical neurones with a number of subcortical neurones located at different levels and in different centres of the brain stem, it is easily understood that injury to the cortical part of this system will put the entire system out of action and impair its functioning as a single whole for a longer or shorter period of time.

Thus, if a rough mechanical trauma caused by surgical intervention evokes massive diffused disturbances spreading over vast regions of the cerebral cortex and at the same time over many cortical-subcortical systems, i.e., disturbances not only extending in breadth, but also penetrating deep into different levels of the brain stem, such disturbances will manifest themselves with particular force and will be of a more prolonged character in those

systems which are directly connected with the extirpated part of the cortex.

"The hemispheres," Pavlov said, "present a special apparatus effecting correlations or connections, an apparatus possessing the highest degree of reactivity; consequently, every disturbance at any part of it must tell upon the whole apparatus, or at least upon many of its remote spots or parts."*

After complete removal of the cerebral hemispheres in a dog motor reactions to any sound were still observed: the dog pricked up its ears and turned the head, which is an unconditioned, orienting, investigatory reflex relating to the subcortical ganglia. In some cases of partial extirpation of the cortex the inhibition, which arose in it, spread, in Pavlov's words, "solely throughout the system of the acoustic analyser, without involving any other analysers,"** but fully embracing only the cortical and subcortical parts of the acoustic system and resulting in complete deafness.

No matter in which region of the cerebral hemispheres the extirpation is made and irrespective of its extent, the first consequence of any partial extirpation is a more or less durable disappearance of conditioned connections (lasting from one day to several weeks and even months).

In milder cases the diffused inhibition arising in the cerebral cortex as a result of extirpation affects only the artificial conditioned connections, i.e., those elaborated in laboratory conditions, and which, therefore, are relatively new and young.

In more severe cases this inhibition also extends to the natural conditioned connections (for instance, stimulated by the sight and smell of food), i.e., to the cortical connections which are acquired under natural conditions

* I. P. Pavlov, *Lectures*, p. 280.
** *Ibid.*, p. 288.

in the course of the ontogenesis, in the process of the individual's development, and which therefore are older, more stable and durable than artificial conditioned connections. This inhibition was not confined to the limits of the cerebral cortex and, in some cases, as was repeatedly pointed out by Pavlov, irradiated also to the systems of the subcortical centres, which effect complex unconditioned reflexes: food, sexual, orienting and others.

The duration of the phenomena of post-operative inhibition in the cortex (and sometimes also in the subcortical regions) depended upon the extent and topography of the destruction, the degree of the general trauma of the brain, the specific properties of the destroyed analyser and the anatomical and functional features of the particular nervous system, or of the organism as a whole.

The restoration of the disturbed functions, their gradual liberation from a more or less diffused inhibition usually take place in strict succession depending on a number of different factors.

The farther the given region from the site of the lesion, the sooner it is liberated from the inhibition, the sooner its functions return to normal. Consequently, conditioned connections effected by the analysers most remote from the place of extirpation recover quickest. The inhibition which first widely spreads over the cerebral cortex, later gradually recedes to its point of origin, being retained for the longest duration in the immediate proximity of the site of lesion.

Unconditioned connections (for example, the unconditioned orienting reflex) are restored quicker than conditioned connections; natural conditioned connections, as we already know, are restored quicker than artificial ones. This brings out not only the different strength of the nervous connections, but also the evolutionary principle: philogenic connections are restored quicker than ontogenic

ones; connections which are ontogenically older recover more quickly than the younger and more delicate ones.

We also know that elementary conditioned connections are rehabilitated quicker than those which result from the highest synthesis and analysis.

Concerning the nature and origin of the above-described inhibition, which first diffusely spreads over the higher parts of the brain, and then gradually concentrates around the site of the lesion, Pavlov said: "It has already been shown in the early lectures that the influence of strong stimuli, and even a conflict between nervous processes, lead to a prolonged inhibitory effect. It is therefore only natural to expect the same to result from a surgical, mechanical destruction of a portion of the cerebral cortex itself."*

Thus, the inhibition in question is regarded by Pavlov as the result and expression of an excessively strong irritation evoked in the brain by drastic surgical interference and coming mainly from the place of destruction (extirpation).

This kind of inhibition was subsequently termed by the founder of the theory of the higher nervous activity *transmarginal* or *protective inhibition*, which defends the nerve cells from ultra-strong or unduly prolonged stimuli exceeding the functional limits of their capacity, and which secures for the nerve cells a state of rest and functional recovery.

Pavlov said: "We recognize as the most constant and general fact in the physiology of the conditioned reflexes that an isolated conditioned stimulation, apparently, conducted into the cortical cells, inevitably leads, sooner or later, and sometimes with astonishing rapidity, to an inhibitory state of the cells and to its uttermost degree—to the sleeping state of the animal. This fact can best be

* I. P. Pavlov, *Lectures*, p. 282.

understood thus: these cells being excessively sensitive and quick to react, very rapidly expend their excitatory substances under the influence of stimulation, and then there sets in another process, to a certain degree protective and economic, the process of inhibition. ... Evidently the same is proved by our exact data showing that, after injury to certain parts of the cerebral cortex, for a long time it is impossible to obtain positive conditioned reflexes from the receptors connected with these parts, their stimulation producing only an inhibitory effect. And when later a positive effect of these stimuli appears, it lasts only a short time and quickly passes over into inhibition; this is an effect typical of the so-called excitatory weakness."*

Consequently, the *first stage* of pathological changes in the higher nervous activity, which comes directly after the operation and in most cases lasts from several days to several weeks, represents the immediate reaction of the brain to local (extirpation) and general trauma (already described above); it manifests itself in the phenomena of diffused inhibition having a protective character.** The cerebral cells subjected to trauma, for a certain time pass over into a state of inactivity and rest, favouring their functional recovery; but gradually resuming their activity the nerve cells for some time continue to manifest a heightened susceptibility to inhibition, an inability to endure strong stimuli and phenomena of accelerated exhaustion.

The *second stage* of pathological changes in the higher nervous activity consists in the fact that the effect of conditioned and unconditioned stimuli becomes more pronounced, exceeding the pre-operation standard of the given animal, and that it greatly resists inhibition: the proc-

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* I. P. Pavlov. *Twenty Years of Objective Study*, p. 452.

** During the Great Patriotic War these phenomena accompanying trauma in the human brain were investigated and described in detail by E. A. Asratyan and the author of this book independently of each other.

ess of extinction, of the development of differentiations, elaboration of conditioned inhibition, etc., is considerably retarded. In other words, here we have, on the one hand, phenomena of heightened excitability and, on the other hand, a weakening of the processes of internal (active) inhibition, which is probably responsible for the increased excitability.

But later experimental investigations carried out by the Pavlov school in the field of pathological disturbances of the higher nervous activity (not relating to the problem of extirpation), revealed in the just mentioned changes of the excitatory process also certain indications of the so-called pathological stasis of excitation.

According to Pavlov, along with the weakening of the processes of internal inhibition after extirpation, there is also observed an unusual slowness and sluggishness of the concentration of the inhibitory process, which he attributes to the unusual *inertness* of inhibition. As shown by N. I. Krasnogorsky, this phenomenon manifests itself not only in the damaged analyser, but in other analysers as well. In the later experimental work of the Pavlov school much attention was devoted to the phenomena of the pathological inertness of the inhibitory process.

"In this manner," Pavlov said, "the endeavour to demonstrate, by extirpating part of the hemispheres, the disappearance of the general normal cortical activity of the functions related to the extirpated part is overshadowed in the first period after operation by the resonance of the surgical blow upon the whole mass of the hemispheres."*

The *third stage* of pathological changes evoked by the extirpation of certain parts of the cerebrum is characterized 1) by a more or less complete extinction of this resonance; 2) by the emergence of a defect in the shape of the disappearance or dissociation of functions, which is a

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* I. P. Pavlov, *Lectures*, p. 283.

direct result of local damage (extirpation); 3) by the process of restoration of functions (complete or partial) and, according to Pavlov's terminology, by the manifestation of "reserve mechanisms"; 4) by the appearance of new pathological changes resulting from the development of scar tissue, from the process of cicatrization in the damaged parts of the cerebrum.

We have already sufficiently dwelt upon the disturbances of cortical functions evoked by lesions (extirpation) located in different regions of the cerebral cortex, i.e., upon local disturbances. We have also stressed that, according to Pavlov, under any localization of the injury to the cerebral hemispheres there always take place simultaneous disturbances of their synthetical and analytical activities which qualitatively differ, depending first of all on the site of lesion and on the specific properties of the particular analyser. As to the process of restoration of functions, we shall not linger on the question of checking or even fully restoring a unilateral lesion with the help of the other hemisphere.

Pavlov's views on the "reserve mechanisms" in the cerebral hemispheres, which to a greater or lesser degree compensate for the defect of functions caused by mechanical damage, essentially consist in the following. As we already know, each analyser has its central part (nucleus), where the concentration of its specific nerve elements is particularly dense and which effects its highest synthetical and analytical activity. At the periphery of the analyser the density of these elements steadily diminishes; but becoming thinner and thinner, they disperse over a considerable area of the cortex. Pavlov considered that these cells which are dispersed in the cortex, "owing to their structure are no longer able to enter into complex interconnections, though they can still perform an elementary synthesis and analysis."* But it is precisely these

* *Ibid.*, p. 294.

very cells that constitute a source of functional compensation when the cerebral cortex is damaged.

In Pavlov's words, such a hypothesis "could very well explain the gradual improvement by practice of the activity of the remnants of the analyser, the functions of which are very limited immediately after the lesion of its nucleus. Ultimately, it should also determine the limits to which such an improvement could extend."*

Thus, when the central part of the analyser is damaged, the improvement of its functions takes place due to the activity of its more or less distant periphery.

Consequently, in the first two stages the process of restoration of functions greatly differs from that in the third stage. In the first case we witness a regression of the massive neuro-dynamical changes caused in the cortex by the surgical trauma and spread over considerable areas, sometimes even over the whole cortex and the subcortical ganglia: no real disappearance or dissociation of functions directly resulting from the destruction of the cerebral tissue takes here place.

When this "resonance of the surgical blow over the whole mass of the hemispheres"** calms down, the widely diffused inhibition gradually disperses and disappears; the correlations between the pocesses of excitation and inhibition in the cerebral cortex little by little return to normal; at the same time those functions which were temporarily overshadowed, or, so to speak, washed away by the considerable neuro-dynamical changes, are restored.***

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* I. P. Pavlov, *Lectures*, pp. 294-95.

** *Ibid.*, p. 283.

*** It may be assumed that the concept of *diaschesis* introduced into the clinic of nervous diseases by the well-known Swiss (but Russian by origin) neuropathologist Monakov derived from the considerable influence of the experimental data of the Pavlov school.

However, at the same time the defect in the activity of the cerebral hemispheres, resulting directly from the destruction (extirpation), begins to manifest itself with increasing force.

In this second case, as we have already seen, quite a different nervous mechanism effects the process of restoration of functions: here it is not a matter of general neurodynamical changes but of a gradually developing compensatory activity of the peripheral parts of the cortical analysers.

But along with the mobilization of these "reserve mechanisms," as Pavlov termed them, there begins to evolve a third stage of pathological changes in the higher nervous activity, changes connected with the cicatrization of the impaired tissues.

The irritative action of this process on the cerebral cortex finds expression primarily in general or local convulsions observed mostly during the formation of scars and commissures in the motor-kinesthetic analyser, or in the adjacent parts of the cerebral hemispheres.

Shortly before a fit of convulsions all conditioned reflexes disappear. The same phenomenon, but lasting for a considerably longer period, is observed immediately after the fit.

The "outburst of excitation," which arises in the place of the scar, first creates around itself a vast zone of inhibition (negative induction). However, under the irritative action of the scar, when the excitation reaches a particularly high degree of tension, the inhibitory barrier vanishes, and the excitation irradiates over the motor analyser, bringing on a fit of convulsions. When the fit is over, the excitatory process concentrates in the point of origin, and around the place of its concentration there arises again a vast zone of inhibition (negative induction), which in most cases spreads over the whole of the cerebral cortex. Besides, in the cells of the motor-kinesthetic

analyser, exhausted by excessive excitation, there probably arise phenomena of transmarginal inhibition.

In some cases heightened exhaustion, and in this connection increased susceptibility of the cortical cells to inhibition, remain for a long time after the fit, becoming more and more intense after each successive fit. Conditioned stimuli evoke a momentary effect which is quickly followed by inhibition (transmarginal); the latter gradually irradiates over the whole of the cerebral cortex and results in a more or less deep sleep (general sleep inhibition).

Thus, the excitatory process becomes pathologically labile, the functional limit of the capacity of the cerebral cells drastically declines and pathologically aggravated phenomena of transmarginal inhibition come clearly to the fore.

In some cases the irritative effect of the scar was observed not in the motor analyser but in other analysers. For example, in the case of a dog this was manifested in the fact that two months after the removal of the frontal lobes any touch, even the most gentle, evoked in the dog a violent defensive response to pain: the formation of a scar in the cutaneous analyser created a pathologically heightened excitability and, in conformity with this, a pronounced hyperaesthesia. Another dog produced an abnormal reaction when the experimenter, food, etc., came into the field of vision of its left eye: the dog turned away, oddly glanced around or ran away. At the same time optical stimuli coming into the field of vision of the dog's right eye produced a normal reaction.

"This can be easily interpreted," Pavlov said, "if we assume that some remaining portions of the scar, which irritated the optical analyser, on one side, produced a distortion of the effect of external stimuli falling on the retina, thus imparting unusual and extraordinary aspects to the visual objects; to this the animal reacted just as it

usually reacts to any concrete, but unusual object. In short, the scar produced a phenomenon of illusion."*

Consequently, various pathological states created by the process of cicatrization in the cerebral hemispheres qualitatively differed depending on the localization and character of this process.

It should be pointed out that disturbances resulting from cicatricial changes considerably complicated and overshadowed the immediate effect of the extirpation of a certain part of the cerebrum.

It was not only a matter of the neuro-dynamical effects of the scar, but in many cases also of its progressive destructive action upon the cerebral tissue. "On the one hand," Pavlov said, "the scar, owing to its mechanical irritation of the surrounding normal parts of the brain, sets up recurrent outbursts of nervous excitation; on the other hand, owing to pressure, distortion and rupture, it progressively destroys the hemispheres."**

Thus, on the basis of his rich experience in the field of experimental extirpation, Pavlov established the following two types of induced pathological changes: a) general changes in the activity of the brain, and b) particular, local changes directly connected with the place of lesion (extirpation).

The general changes include: 1) the initial "resonance of the surgical blow over the whole mass of the hemispheres" (Pavlov); this manifests itself in the general inhibitory action of the trauma in the cerebrum and in the disappearance of all conditioned connections; sometimes it also affects certain unconditioned reflexes (this is termed by us "the first stage"); 2) the phenomena of heightened susceptibility to exhaustion and inhibition accompanied by a drastic decline in the functional limit of the capacity

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* I. P. Pavlov, *Lectures*, p. 285.
** *Ibid.*, p. 280.

of the cortical cells; these phenomena present, so to speak, a transition to a number of new pathological changes, where, in the foreground, there is observed a weakening of the processes of internal inhibition and a particular inertness of the latter, and where at the same time there are disturbances of the excitatory process (the second stage); 3) general neuro-dynamical changes caused by the phenomena of cicatrization, accompanied in most cases by fits of convulsions (the third stage).

Local disturbances include: the disappearance of functions and their dissociation, and the defects of cortical synthesis and analysis directly connected with the site of lesion (extirpation) which gradually manifest themselves already in the second stage. In the third stage they are supplemented, on the one hand, by phenomena of compensation of the disturbed functions, the nervous mechanisms of which have already been discussed by us in the light of Pavlov's theory, and, on the other hand, by local pathological disturbances connected with processes of cicatrization.

It must be emphasized that all the above-described disturbances of the activity of the cerebral cortex affect to a certain degree also the functions of the subcortical regions. The neuro-dynamical changes taking place in the cerebral hemispheres are echoed at different levels and in different systems of the brain stem.

Pathological changes are observed in the unconditioned orienting reflexes, in the alimentary, self-defence and sexual complex unconditioned reflexes (instincts), in the central regulation of vegetative functions (disturbances of the thermo-regulating mechanisms, of metabolism, of trophic functions, etc.).

Thus, disturbances caused by more or less serious damage to the cerebral hemispheres tend to spread over the whole organism, its external and internal vital activity, its somatic and vegetative functions.

Unfortunately, this branch of patho-physiology of the higher nervous activity, devoted to the study of disturbances resulting from the experimental destruction of different parts and sections of the cerebral hemisphere, and artificially induced "organic lesions" of the brain, came into being in the main at a comparatively early stage of development of Pavlov's theory.

Consequently, the facts relating to the study of the types of the higher nervous activity, the so-called phasic phenomena in the cortex, the concept of transmarginal or protective inhibition thoroughly elaborated later on, etc., were not sufficiently elucidated in this branch of the pathology of the cerebral hemispheres.

"It is regrettable," Pavlov stated, "that in the period when the majority of our experiments with extirpation were performed (the earlier period of our research), we had not yet any knowledge of the different types of the nervous system in our experimental animals and of the pathological states arising in the hemispheres under functional influences. Had we possessed this knowledge the utilization of the experimental material obtained from extirpation would probably have been more extensive and profound."*

In order to know for certain which phenomena of the post-operation disturbances of the higher nervous activity resulted from a change of its general properties and which were "the result of the destruction of certain structures," it is necessary, according to Pavlov, thoroughly to investigate the general changes of excitability, the conditions under which a positive stimulus is transformed into an inhibitory one, the mobility of the cortical processes, etc.

Concluding his lectures devoted to experiments with extirpation, Pavlov modestly stated: "In describing the

* I. P. Pavlov, *Lectures*, p. 286.

cases in the present lecture I do not make the slightest claim to have given a satisfactory explanation of the nervous mechanism underlying all the deviations from normal in the behaviour of the dogs after surgical damage of the brain." "My sole aim," he continued, "has been to show that problems relating to this mechanism are the legitimate province of physiology and to demonstrate that there is a reasonable possibility of their solution."*

6

THE STUDY OF THE HIGHER NERVOUS ACTIVITY UNDER EXPERIMENTALLY INDUCED DAMAGE TO THE BRAIN CONDUCTED AFTER PAVLOV'S DEATH

The experimental work of Pavlov and of his school in the field of extirpation of the cerebral hemispheres was continued by his disciple E. A. Asratyan (1935-1951) together with a number of his collaborators. Experimentation was carried out not only on dogs but also on birds and other animals. The results of the complete removal of the cerebral cortex were thoroughly studied in forty dogs; this substantially supplemented the experimental data obtained by G. P. Zeliony, O. S. Rosenthal, N. F. Popov and others.

The decortication of the cerebrum was performed in two stages, first the cortex of one hemisphere was excised and some time later the cortex of the second hemisphere.

The first phenomenon that attracted E. A. Asratyan's attention was the peculiar disturbance of the regulation of the cardio-vascular and respiratory systems observed

* I. P. Pavlov, *Lectures*, p. 327.

during a period from seven to thirteen days after the second operation. Any slight muscular effort, any insignificant movement of the muscles, evoked in these dogs a pronounced and durable dyspnoea, a considerable quickening and augmentation of the cardiac rhythm and profuse salivation. These phenomena made E. A. Asratyan assume that the cerebral cortex takes part in regulating the activity of the central nervous apparatus of the cardio-vascular and respiratory systems, just as it participates in the regulation of somatic functions. Decortication brings about a disturbance of these regulative influences. A number of other pathological changes of the vegetative functions are also observed: considerable disturbances of thermo-regulation and gastro-intestinal activity, a lowered resistibility to various pathogenic factors (for example, to infection), disturbances of metabolism* and trophic changes of the skin.

Whereas K. M. Bykov regards the cortical regulation of vegetative functions as a manifestation of conditioned reflex activity, E. A. Asratyan mainly stresses the general trophic influence of the cortex upon the lower centres of the autonomous nervous system. The one, however, does not exclude the other.

Also of interest are E. A. Asratyan's observations showing that when the cerebrum of a dog is fully decorticated some individual (or to be more precise, typological) features still persist. This relates to the specific properties of food excitability, to the general mobility of the animal, to its reactivity to tactile stimuli.

Complete decortication causes a derangement in the normal rhythm of the sequence of wakefulness and sleep: this rhythm is considerably quickened.

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* Disturbances of metabolism in decerebrate dogs were also studied by N. T. Shutova.

Narcotization (by ether and chloroform) induced even in decorticated dogs a pronounced phase of excitation followed by deep narcotic sleep.

A series of valuable studies was devoted by E. A. Asratyan and his collaborators (1936-1948) to the role of the cerebral cortex in the development of adaptive changes in the damaged organism. The lesions were of the following nature: amputation of one or two paws, sectioning of the posterior or lateral half of the spinal cord, its partial longitudinal sectioning, the cutting of its posterior roots in the cervical or lumbar segments, the sectioning and cross-suturing of various nerves, the destruction of labyrinths, etc.

After the disturbed and lost functions were restored by long training and by developing various compensatory adaptive phenomena, the cerebral cortex of dogs (as well as of other animals taking a lower place in the evolutionary scale) was fully removed.

The following results were obtained: all the adaptive phenomena, which developed in the dogs prior to the decortication, completely vanished and were not recovered, no matter how long the animals lived, although it was possible to preserve some of them for three years.

These experiments were carried out on a certain group of dogs in reverse order, i.e., first the cerebrum or its cortex was extirpated and then the above-mentioned operations were performed (amputation, partial sectioning of the spinal cord, destruction of the labyrinths, etc.). The experiment showed that in these conditions no development of adaptive phenomena was observed; neither was it possible to induce it.

The experiments convincingly proved the great importance of the cortical activity in higher animals for the development of adaptive phenomena in the damaged organism. The picture is altogether different in lower animals; for instance, in birds after the removal of the

cerebrum the phenomena of adaptation developed very slowly, and as a matter of fact were feebly pronounced; in lower vertebrates the removal of the cerebrum did not produce any substantial influence on the development of such phenomena.

Proceeding from Pavlov's concept of protective inhibition, from the experience of Pavlov's psychiatric clinic in sleep therapy based on this concept (1935-1941), and from subsequent experiments performed by M. K. Petrova on dogs subjected to prolonged narcotic sleep, E. A. Asratyan and his collaborators carried out in the period 1941-1945 numerous experiments on animals (dogs, cats, rats, frogs); the aim of these experiments was to study the influence of sleep therapy on the restoration of functions in cases of various artificially induced traumatic lesions of the nervous system (complete or partial sectioning of the spinal cord, contusion or commotion of the brain, surgical lesion of the cerebrum, etc.). Utilizing mainly bromides, hedonal and urethane, E. A. Asratyan in most cases obtained good therapeutic results; subsequently he began to apply sleep therapy in the treatment of traumatic affections of the human nervous system, of which a more detailed description will be given in a subsequent chapter.

Among other experimental investigations carried out in this field (i.e., in the field of extirpation) by Pavlov's disciples after his death, are the works of K. S. Abuladze, I. Y. Zelikin and O. S. Rosenthal (1941), who studied the disturbances induced in dogs by the removal of the whole cortex of one hemisphere and of the motor analyser in the other.

Since Pavlov's death a particularly great amount of experimentation connected with the extirpation of different parts of the cerebral hemispheres has been done by O. S. Rosenthal (1938-1948); removal of the cortex of one hemisphere and of the motor region of the other pro-

foundly disabled the dog; when the upper halves of both hemispheres were excised, the elementary conditioned reflex activity was well retained, but the co-ordination of complex motor acts was definitely lost, although its slow improvement could be observed; the removal of the motor or of the cutaneous analyser particularly manifested itself in a drastically delayed development of corresponding differentiations; a dog with a fully removed cortex of one hemisphere, which first displayed a number of profound disturbances of the higher nervous activity, was able to make good within a few years all the defects and almost in no way differed from normal dogs.

Summing up his numerous experimental investigations, O. S. Rosenthal stresses the following factors: 1) the great diversity and multiformity of functions of individual cortical regions; 2) the substitutive function highly developed in dogs; 3) the ability of any undamaged cortical region to effect the elementary functions of a damaged one; 4) the relatively specific character of the cortical regions; 5) the absence of equipotentiality under normal conditions and its appearance when the cortex is damaged; 6) the definite significance of the limitrophe areas in dogs; 7) the close functional interdependence between the architectonic fields; 8) the strongly pronounced derangement of the nervous activity in dogs after the lesion of the later philogenic formations (the frontal lobes, the motor region).

Of great interest is the experimental work done by V. S. Deryabin (1946) who established a number of changes in the higher nervous activity connected with the damage of the thalamus and the hypothalamic area.

Finally, mention should be made of the investigations of K. M. Bykov and his collaborators (A. D. Slonim, A. L. Komendantova and others); they deal with the effect of complete or partial removal of the cortex on the activity of the internal organs.

With the removal of the cerebral hemispheres in pigeons the conditioned thermo-regulatory reflexes disappeared and could not be restored; in bats similar circumstances irretrievably destroyed the conditioned reflexes to time. After a bilateral extirpation of the pre-motor region in dogs, all conditioned reflexes tested on the internal organs (such as bile secretion, gastric motor activity, thermo-regulation, etc.) persisted; however, the rate of the influences exerted by the cortex on the activity of the internal organs (mainly by quickening or retarding the emergence and development of these reactions) was somewhat changed. The ability for quick and adequate adaptation to the changing external environment was lost.

Investigations connected with experimentally induced damage to the cortex through artificial derangement of blood circulation were started by L. A. Andreyev already in Pavlov's lifetime and continued after his death. By ligating both common carotid arteries as well as the vertebral arteries he caused an anemization of the cortex and studied the changes thus evoked in the dog's higher nervous activity and the process of their compensation.

Within two weeks after the operation a complete disappearance of all conditioned reflexes took place. In the course of the rehabilitation of conditioned connections the processes of internal inhibition were for a certain time greatly weakened. It proved altogether impossible to recover the long delayed conditioned reflexes and fine differentiations. Nevertheless, these experiments showed that the severe damage to the cortex was to a certain extent eliminated by collateral blood circulation.

L. A. Andreyev's experiments were continued and further developed by E. A. Asratyan (1948) who also perfected the method and technique of investigation (by increasing the static pressure in the subdural space). The anemization of dogs lasted from six to twenty minutes. The dogs survived for a long time after twelve, fourteen,

sixteen and even twenty minutes of anemization. In these animals more or less pronounced disturbances of the higher nervous activity were observed, mainly in the shape of phenomena of diffused inhibition and pathological inertness of the cortical processes.

The somatic functions were affected quicker and more profoundly than the vegetative ones; the philogenically younger functions suffered more and for a longer duration than the philogenically older functions.

The extent of all disturbances and their general character depended in large measure on the typological peculiarities of the animals.

Also of definite interest are the experiments of M. A. Ussievich (1948) who investigated by the method of conditioned reflexes the motor and secretory reaction of dogs prior to and after lobotomy (i.e., the sectioning of the white matter in the region of the frontal lobes).

Unilateral lobotomy brought about, along with disturbances of movement, a drastic change in the reaction of the animals to conditioned stimuli: some animals displayed an aggressive attitude towards the experimenter never observed before.

After bilateral lobotomy all the above-mentioned phenomena proved to be even more strongly pronounced. The conditioned reactions revealed a sharp weakening of the inhibitory process and a lesser lability of cortical processes.

At this point we could conclude this chapter, devoted mainly to a brief description of the first stage in the development of the patho-physiology of the higher nervous activity, as well as of some additions introduced after Pavlov's death. However, we deem it necessary to dwell at length on the significance and possible limits of the application of the above experimental data to man.

7

THE POSSIBILITY OF APPLYING THE EXPERIMENTAL DATA CITED IN THE PREVIOUS CHAPTERS TO MAN

There is hardly any doubt that the artificially induced pathological states of the higher nervous activity in animals described in this chapter, are rough models, or so to speak, simplified schemes of certain diseases of the human brain. Apparently, this is a question of diseases caused by destructive lesions more or less spread over the brain and connected with a certain destructive influence which evokes now more delicate, now more drastic structural changes in the nerve tissue. Consequently, we have here so-called organic diseases (which clinical medicine usually distinguishes from functional diseases), and in particular, focal and other similar affections (traumas of the brain, haemorrhagic extravasation, destructive foci of an infectious and toxic origin, tumours, etc.). The analogy becomes especially marked if the data obtained from experiments with extirpation in animals are compared with the pathological states caused by traumatic lesions of the human brain or by the surgical removal of certain of its parts.

However, even such analogy is of a highly relative character and must be drawn with great caution.

Along with common features, one must always take into account the fundamental differing features considerably distinguishing the human higher nervous activity from that of those animals closest to man in evolutionary respect.

One must always bear in mind the socially determined human behaviour, the labour activity, which is effected collectively with the help of implements and tools, the speech function (and all the activities connected with it), so characteristic of man.

Nor must one forget the qualitative peculiarities of the human higher nervous activity connected with the development of the second signalling system (i.e., the system of cortical functions which find direct expression in speech and are connected with it in one way or another).*

Such are the facts relating to the physiological conditions of the activity of the brain. But all that has been said above applies in no lesser degree to the pathological conditions. Comparing the pathological disturbances in the activity of the higher parts of the central nervous system in animals with those in man and establishing their common features, one must not overlook their qualitative distinctions.

There is no doubt that in any diseases of the human brain (including all kinds of organic, and in particular, traumatic lesions) the disturbances of the normal activity of the brain find a qualitatively specific expression in the social interrelations of the patient, in his labour activity and speech function. At the same time there is, undoubtedly, always present a certain change in the interaction of the basic functional systems of the human cerebral cortex, which Pavlov terms the first and the second signalling systems.

Nevertheless, in the human brain too there take place disturbances of cortical synthesis and analysis; general and local derangements in the activity of the higher parts of the central nervous system; neuro-dynamical changes in the shape of disturbances of movement and interaction of processes of nervous excitation and inhibition in the cortex and subcortical regions; different successive phases of pathological changes in the cortical and subcortical dynamics.

This in no way underrates the great importance of

* Pavlov's theory of the first and second signalling cortical systems will be discussed in a later chapter.

descriptive clinical work; nobody wants to replace clinical psychiatry or neuropathology by the patho-physiology of the higher nervous activity (as some try to picture it); nobody denies the qualitative multiformity of clinical symptomatology, which has been studied for hundreds of years.

However, the extreme meagreness of our knowledge of the patho-physiology of the higher parts of the human central nervous system makes the data obtained by the Pavlov school all the more important, indispensable and valuable; this meagreness demands that close attention be paid to these data and that further research be done in the field of the patho-physiology of the human higher nervous activity, without repudiating in the least the data obtained from experimentation on animals.

In the light of Pavlov's theory it is necessary to revise and approach anew the problem of the interrelation between the "functional" and the "organic," as hitherto interpreted by clinical medicine.

In both cases there take place functional disturbances in the shape of neuro-dynamical changes, pathological changes of movement and of the interaction of nervous processes in the brain tissue.

But if in the first case these disorders are connected only with the most minute structural changes in the nerve cells, or, to be more exact, neurones, with changes most of which are beyond the reach of microscopic investigation, bearing an intramolecular character and closely linked with trophic, metabolic dissociations, in the second case the picture is altogether different.

Here it is a matter not only of the most minute structural disturbances, but of cruder affections in the shape of destructive foci, diffused or systemic degenerative changes, etc. Here, in other words, disturbances that are accessible to microscopic and even macroscopic investigation come to the fore.

When dealing both with "functional" and "organic" diseases, the clinician encounters neuro-dynamical changes, disturbances of movement and of the interaction of nervous processes, morbid changes in the interrelations between different parts, levels and systems of the brain; but along with a number of common features in these neuro-dynamical changes and in their clinical symptoms one must take into account their more or less pronounced distinctions, which are due to differences in the derangements of correlations between the dynamics and structure, as well as to different, in the broader sense of the word, patho-morphological substrata of the disturbances of the brain activity.

We already know, for example, that in the case of "organic" lesions the neuro-dynamical changes are closely linked with phenomena of central excitation and central disappearance of functions, as well as with processes tending to compensate the defect. This to a considerable degree is responsible for the qualitative peculiarities of the clinical picture.

Thus, the experimental data contained in this chapter characterize the general and local pathological changes of the higher nervous activity in animals, caused by lesions of the brain of various size and localization and, in the main, can be applied to man with the above-mentioned reservations, the differences in no way excluding the common features.

Comparison of the data obtained from experiments on animals with the data of clinical symptomatology undoubtedly contributes to the patho-physiological interpretation and elucidation of the pathogenesis of various neuropathological and psycho-pathological syndromes.

The modelling of various lesions of the brain on animals is of great importance also for the elaboration of an experimental therapy based on pathogenesis and proceeding from patho-physiological premises.

We know that already in his first work devoted to the study of the activity of the cerebral cortex, Pavlov closely linked his investigations with elaboration of an "experimental psycho-pathology based on a study of animals." His last (23rd) lecture on the work of the cerebral hemispheres was devoted to the "experimental results, obtained with animals, in their application to man." He wrote: "If we must be cautious in applying to man our knowledge concerning the function of such organs in higher animals as the heart, stomach and others, similar as they are to those of the human being, and test the validity of the comparison by its agreement with the actual facts, then how great must be our reserve in transferring to man our only recently acquired exact scientific data on the higher nervous activity of animals. For it is just this activity which so sharply distinguishes man from animals and places him in such a dominant position in the animal world. It would be the height of presumption to regard these first steps of the physiology of the cerebral hemispheres—complete in relation to programme but not to content—as solving the grandiose problem of that supreme mechanism of human nature. Consequently, any rigid regulation of the work in this field at present would only testify to extreme narrow-mindedness. But, on the other hand, a very simplified treatment of this subject on the part of natural science for the time being, of course, must not encounter animosity, which, unfortunately, also happens not infrequently.... In the light of what has been said in all previous lectures one can hardly dispute that the higher nervous activity exhibited by the cerebral hemispheres rests on the same general foundations in man as in the higher animals, and that, therefore, the elementary phenomena of this activity in them must also be similar both in normal and pathological states."*

* I. P. Pavlov, *Lectures*, pp. 345-46.

ESSAY II

PATHOLOGICAL CHANGES OF THE HIGHER NERVOUS ACTIVITY IN ANIMALS RESULTING FROM FUNCTIONAL INFLUENCES

1
EXPERIMENTAL NEUROSES

Whereas in the previous essay we were concerned with the pathological changes of the higher nervous activity induced in animals as a result of more or less extended and differently localized lesions of the cerebral cortex, in this essay we shall pass over to the problem of pathological states caused by various noxious influences of a functional character on the higher parts of the central nervous system of the animal.

If in the previous essay we met, as it were, with simplified, rough experimental models of the so-called organic cerebral diseases, this essay will chiefly deal with similar models of the so-called functional diseases of the human central nervous system.

First of all, we shall have to dwell upon the pathological states experimentally induced in dogs in Pavlov's laboratories, in response to the difficult tasks demanded of their nervous systems in the course of experimentation. The study of these functional pathological states was closely connected with the development of the theory of various types of the higher nervous activity, and its origin, as we shall see later, can be traced back to 1909-1910.

Such states were described by Pavlov as *experimental neuroses*; however, it would not be quite correct to regard them as full analogues of human neuroses and stop at

that. While some of them actually are what we may call simplified models of human neuroses, others are not.

Not specifying for the moment this problem, we shall only stress the fact that for the first time in the history of science Pavlov's laboratories succeeded in obtaining experimentally induced disturbances of the activity of the higher parts of the animal central nervous system, which present the simplest models, or rough schemes, of certain neuropsychic diseases both of psychogenic and somatic origin. In some cases these models are in a certain measure analogous to human neuroses, in other cases—to human psychoses. However, it should not be forgotten that along with certain common features they always have marked differing features.

While studying various forms of experimentally induced functional disturbances of the higher nervous activity in animals, Pavlov at the same time invariably strove to build up an experimental therapy of these disturbances based on pathogenesis. This brought the study of functional pathological states of the cerebral cortex closer to the investigations in the field of the pharmacology of the higher nervous activity.

The development of the theory of experimental neuroses was also considerably advanced by researches into the so-called phasic states of the cortex; the latter were first established in the nerve fibres by N. E. Wedensky and subsequently attracted Pavlov's attention in connection with his study of pathological states resulting from functional influences on the higher parts of the central nervous system. Pavlov's concept of protective inhibition was also developed in close alliance with these problems.

The study of experimentally obtained functional disturbances in the activity of the higher parts of the animal's brain greatly helped to bring Pavlov closer to the interests of the clinic of nervous and neuropsychic

diseases. As proved by further practice, investigations in this field were of great value also for other medical branches, including the clinic of internal and skin diseases, oncology, pediatrics, etc. Of particular importance in this respect is the research done by M. K. Petrova, M. A. Ussievich, N. I. Krasnogorsky and others.

At present one can hardly doubt that the problem of interrelation between functional pathological disturbances of the higher parts of the central nervous system and somatic diseases is one of the most urgent problems confronting Soviet medicine, a problem which has considerably outgrown the bounds of the neuropathological and psychiatric clinic.

It may be hoped that in the course of studying the pathological changes of the higher nervous activity caused by various noxious functional influences, maximum contact will be established between the patho-physiology of the higher nervous activity, on the one hand, and general patho-physiology, on the other.

2

THE THEORY OF TYPES OF HIGHER NERVOUS ACTIVITY AND EXPERIMENTAL NEUROSES

"The experiments to which our animals were subjected," Pavlov stated, "in other words, the demands we made upon their nervous systems, at first, having not even the slightest idea as to the limits of the endurance of their brain, led in some instances to chronic disturbances of the normal activity of the cerebral hemispheres. Here I imply exclusively disturbances of a functional character and origin, and not due to surgical trauma. From some of these disturbances the animal recovered gradually under the influence of rest alone when the

disturbing experiments were discontinued; in other cases the disturbances proved to be so persistent as to require special therapeutic measures. Before our eyes the physiology of the cerebral hemispheres turned into their pathology and therapy. The pathological states of the hemispheres in different individual animals under similar injurious influences varied greatly. In some dogs these influences caused severe and prolonged disorders; in others the disorders were only slight and fleeting; while yet others remained practically unaffected. The deviation from normal assumed in different dogs quite different aspects. Since this diversity was obviously determined by differences in character and type of the nervous system of individual animals, it is important, before discussing the pathological states of the hemispheres, to say a few words about the types of nervous system found in our dogs."*

It is noteworthy that in the history of development of the theory of higher nervous activity, too, the two problems raised by Pavlov in the above statement proved to be closely interconnected.

Pavlov made his first mention of the types of nervous system in his article "Further Advances of the Objective Analysis of Complex Nervous Phenomena, and Its Comparison with the Subjective Concept of These Phenomena" based on the experiments of P. A. Nikolayev and published in 1909-1910.**

Here Pavlov's attention was attracted by dogs in which no conditioned inhibitors could be developed; instead there always and invariably appeared conditioned reflexes of the second order—in these animals, contrary to all other experimental dogs, it proved absolutely impossible to obtain a transition from conditioned excita-

* I. P. Pavlov, *Lectures*, p. 248.

** I. P. Pavlov, *Twenty Years of Objective Study*, p. 90.

tion to conditioned inhibition, although the reinforcement was repeatedly and frequently discontinued. Pavlov was inclined to see in this phenomenon a manifestation of certain insufficiency of the central nervous system, and at that time included such animals into the type of those having "a weak nervous system."

Approximately at that time he made an attempt to define typological variations on the basis of the specific properties of irradiation and concentration of the inhibitory process;* in the subsequent years he based them on the peculiarities of the animal's behaviour in free, natural conditions and in the experimental stand; in this, however, he proceeded from the analysis of the correlation between the excitatory and inhibitory processes in the animals, as well as of the correlation between wakefulness and sleep (general sleep inhibition). It was observed, for example, that animals which were very lively and active under natural conditions, often very quickly fell asleep when fastened on the stand; on the contrary, slow, sedate and quiet dogs behaved in the stand in full conformity with the demands made upon them by the experimenters, and did not reveal any disposition to sleep, i.e., to the irradiation of inhibition and its transition to general sleep inhibition.**

Although no comprehensive classification of the types of higher nervous activity was given in Pavlov's works at that time, it can be assumed that in general the classification began already then to take shape in laboratory practice. P. M. Nikiforovsky, for instance, in his M.D. thesis, which originated in Pavlov's laboratory and was published in 1910,*** mentioned three groups of dogs: a) showing a predominance of inhibition; b) showing a

* *Ibid.*, p. 167.

** *Ibid.*, pp. 298-99.

*** P. M. Nikiforovsky, *The Pharmacology of Conditioned Reflexes as a Method of their Study*, Dissertation, 1910.

predominance of excitation; and c) the equilibrated group.

The study of the types of higher nervous activity in dogs became particularly brisk and made particularly rapid strides after the first experimental neuroses were obtained in Pavlov's laboratories (1921-1923). Since that time there has been an ever-growing interest in this problem and, at the same time, a steady growth of experimentation in this field.

Pavlov's first special work substantiating the classification of the types of higher nervous activity and summing up the considerable factual material already accumulated, was the paper read by him on December 6, 1927, before the Russian Surgical Society, at the memorial session dedicated to N. I. Pirogov. The paper was entitled "A Physiological Study of the Types of Nervous Systems, i.e., of Temperaments."* The subsequent accumulation and generalization of experimental data considerably supplemented and rounded off the theory of types of higher nervous activity. This theory was expounded by Pavlov in a most detailed and elaborate form in 1935 in the article "General Types of Animal and Human Higher Nervous Activity."**

However, before characterizing the classification of the types of nervous systems, we must touch on the essence of the concept "type" as interpreted by Pavlov.

"Human and animal behaviour," he wrote, "is determined not only by congenital properties of the nervous system, but also by the influences to which the organism has been continuously subjected during its individual existence; in other words, it depends on constant education and training in the broadest sense of these words. . . . Consequently, since it is a question of the natural type

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 459.
** *Ibid.*, p. 651.

of nervous system, one must take into account all the influences to which the organism has been exposed from the day of its birth to the present moment."*

A type (phenotype) of the higher nervous activity was, in the last analysis, regarded by Pavlov as a blend of congenital characteristics and changes produced by the external environment and acquired in the course of the individual existence of the organism, "since the animal is exposed from the very day of its birth to the most varied influences of the environment, to which it must inevitably respond with definite actions, often, eventually, fixed for life."** Thus, for Pavlov the concept of type of higher nervous activity became, in the last analysis, equivalent to the concept of character (in which, of course, are reflected to a certain degree also the peculiarities of temperament). A definite complex of fundamental properties of nervous activity is inherent in each type.

These properties are: in the first place, the *force* of the basic nervous processes—excitatory and inhibitory—which "always constitute the whole of the nervous activity" (I. P. Pavlov); in the second place, the *equilibrium* between these processes; and, in the third place, the *mobility* of these processes.

While all these properties exist and act simultaneously and in close interconnection, "they provide the highest adaptation of the animal's organism to the surrounding world, or, in other words, the complete equilibration of the organism as a whole with the external environment, i.e., they secure the organism's existence. The significance of the force of nervous processes is clearly shown by the fact that in the surrounding medium there arise (more or less often) unusual, extraordinary developments,

* *Ibid.*, p. 653.
** *Ibid.*, pp. 720-21.

powerful stimuli; and, naturally, other external conditions of a similar and even greater force not infrequently necessitate the suppression or retardation of the effects of such stimuli. And the nervous cells must endure this extraordinary tension in their activity. From this also follows the importance of equilibrium between both processes, their equal strength. Since the organism's external environment is constantly—and often powerfully and abruptly—fluctuating, both processes must, so to speak, keep pace with these fluctuations, i.e., they must possess great mobility and be able, in compliance with the demands of the external conditions, rapidly to recede, to give preference to one stimulus before another, to excitation before inhibition and vice versa."*

The definition of the types of higher nervous activity was usually accomplished by the following methods: a) observing the general behaviour of the animals in their natural environment; b) experimentally investigating their behaviour in the stand, and comparing the results thus obtained with those relating to the general observation of the animals' behaviour; and, finally, in a number of cases c) experimentally investigating the behaviour of the animals outside the stand, on the floor, in conditions of their free locomotion (M. K. Petrova, Y. P. Frolov, E. M. Kreps, V. V. Rickman and others).

In order to define and describe the specific properties of the force, equilibrium and mobility of the nervous processes, a number of special experimental methods and functional tests were elaborated.**

Depending on the force of nervous processes (excitatory and inhibitory) the experimental animals were divided into representatives of the weak and strong type of nervous system.

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 651-52.

** Since Pavlov's death they have been perfected and detailed by V. V. Rickman, and more recently by Kolesnikov and Troshikhin.

It was recognized that the fundamental feature of the weak type of higher nervous activity consists in the rapid exhaustion of the cortical cells, particularly under the action of very strong or protracted monotonous stimuli and, hence, in their heightened susceptibility to inhibition (a low functional limit of the working capacity of the cortical cells accompanied by a rapid development of transmarginal inhibition, as well as considerable external inhibition, and easily irradiating internal inhibition). The weakness of the excitatory process was for long regarded as the most characteristic feature of this type. However, further investigations showed that in many similar cases there is in evidence not only a weak excitatory process (which also finds expression in the impeded establishment of new conditioned connections), but also a deficient process of internal, *active* inhibition, along with a heightened tendency towards phenomena of *passive*, mainly transmarginal (or protective) and external inhibition.

According to Pavlov, in the type of dogs just described, "the cortical cells possess only a small reserve of excitatory substances, or are supplied with extraordinarily destructive substances."* Thorough study of the weak inhibitory type has become the object of numerous experimental investigations by the Pavlov school (M. K. Petrova, D. S. Fursikov, E. M. Kreps, Y. P. Frolov, V. V. Rickman, A. D. Speransky, N. V. Vinogradov, S. N. Virzhikovsky, D. I. Soloveychik, E. Z. Strogaya, G. V. Skipin and others). For a number of years strongly pronounced passive-defensive reactions were regarded as the most characteristic, specific feature, inherent in this type alone.

In 1927-1928 one of the Pavlov laboratories for the first time investigated a dog in which, contrary to all

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 453

previous cases, greatly accentuated passive-defensive reactions were combined with a strong type of higher nervous activity; it was assumed that this unusual combination depended on the peculiarities of the ontogenesis, on the conditions of the individual development of the animal which was born and reared in the kennel, i.e., in captivity, in the cage (A. G. Ivanov-Smolensky).

Thus, it became necessary to investigate the influence exerted upon the formation of the type of higher nervous activity by the properties of the external environment in which the individual development of the animal took place, by the peculiar conditions which surrounded it, by the specific features of its ontogenesis. In order to verify the correctness of the above hypothesis, puppies from the same litters were taken in Koltushi, as desired by Pavlov, and each litter was divided into two groups: one half of the puppies from the very day of their birth were kept in the kennel; the others were given full freedom. Thus, some of the animals were raised in conditions which greatly limited their acquaintance with the surrounding world and the development of their adaptive nervous mechanisms; the others grew in conditions of freedom and obviously encountered constant dangers and difficulties which the first group of dogs did not have to overcome. It turned out that the dogs raised in the kennel, in contrast to those which grew up free, displayed strongly pronounced passive-defensive reactions when their mode of life was changed, when new, unusual circumstances arose, or even when the slightest changes took place in the surrounding world (S. N. Virzhikovsky, F. P. Mayorov, L. O. Seewald). Thus, the influence exerted on the formation of the type of higher nervous activity by the conditions of the external environment in which the individual development of the animals takes place, and under which they are raised, was proved experimentally.

Concerning these experiments Pavlov wrote: "It is obvious that when the puppies first appeared in the external environment they were provided with a special reflex, which is sometimes called a panic reflex, but which I should suggest terming an initial and temporary reflex of natural caution. As soon as the acquaintance with the new environment begins it is inevitable to wait some time for the consequences of any new stimulation, no matter which receptor it affects, i.e., to abstain from any new movement and to repress the existing movement, since it is not known what the new phenomenon promises the organism—whether it is harmful, useful, or of no consequence at all. And only in the course of the gradual acquaintance with the environment is this reflex little by little replaced by a new, special, investigatory reflex, and, depending on its effect, by other corresponding reflexes. The puppy, which was not given the opportunity independently to gain this practical experience, retains that persisting temporary reflex for a very long time, if not for life, and the reflex constantly disguises the real force of the nervous system. What a vital pedagogical fact this is!"*

It can be assumed that under favourable ontogenic conditions the animal belonging to the weak type may lose its disposition to passive defensive reactions. Indeed, already in Pavlov's lifetime, such a case, subsequently described by V. I. Pavlova, was observed and investigated.

If, in accordance with the *principle of the force* of nervous processes, all experimental animals were divided in two groups—the strong and weak types—the representatives of the strong type of higher nervous activity were divided, in accordance with the *principle of equilibrium* between the excitatory and inhibitory processes in the cortex, also in two groups—equilibrated and unequi-

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 655-56.

librated. It should be stressed that this concerns mainly the highest, internal, or active inhibition inherent only in the cerebral cortex, which, along with the excitatory process, secures a constant equilibration of the organism with the external environment and helps to distinguish between the nervous activity conforming to the given conditions from the activity which does not conform to them and is therefore susceptible to inhibition.

In the first place those animals were subjected to investigation in which, along with an easy and quick establishment of positive conditioned connections and with a great ability to endure super-powerful and protracted stimuli, i.e., with a high functional limit of the working capacity of the cortical cells, the development of different kinds of internal inhibition proved to be very slow and proceeded with difficulty. Persistent attempts by the experimenter to obtain such inhibition not infrequently evoked in the animals vigorous resistance, destructive and aggressive reactions, general motor excitation, etc. Thus, along with a strong excitatory process, these animals manifested an obvious deficiency of the process of internal or active inhibition, that is, a more or less distinct prevalence of the excitatory process over the inhibitory one. It should be pointed out that here we have the predominance of the relatively stronger excitatory process over the inhibitory, rather than the weakness of processes of internal inhibition; consequently, it is a question of insufficient equilibrium between the two processes.

It goes without saying that the animals described above are representatives of the strong, but unequilibrated type of higher nervous activity, of the excitable, or, using Pavlov's terminology, impetuous type of nervous system.* In the Pavlov school a considerable num-

* However, V. P. Golovina in 1938 described a dog which she regarded as belonging to the weak, unequilibrated, excitable type,

ber of experimental investigations were devoted to an all-round study of animals belonging to this type. (N. R. Schenger-Krestovnikova, M. K. Petrova, L. N. Fyodorov, F. P. Mayorov, I. R. Prorokov, V. V. Yakovleva, M. A. Ussievich, S. I. Galperin and others). Pavlov devoted close attention to the point that gradual and insistent training of the processes of active inhibition may, to a considerable degree, eliminate the phenomena of heightened excitability and contribute to the equilibration of both cortical processes which he regarded as another proof of the variability of the type under the influence of the external environment, "under the influence of lifetime training."*

In contradistinction to the strong, but unequilibrated, excitable type of the higher nervous activity there is a group of animals of the strong and equilibrated type. The general behaviour of the latter is already sufficient to divide them, as Pavlov expressed it, into *lively* and *quiet* animals. The experimental investigation of the conditioned reflex activity in such animals showed that a fairly good mobility of the cortical processes is peculiar to the first category of animals, whereas a certain stagnation and inertness of these processes is manifest in the second. Hence the *principle of the mobility* of nervous processes is the underlying principle for the subdivision of the strong and equilibrated type of animals into two groups.

Pavlov said: "Thus we have a perfect group of strong and equilibrated dogs. However, the representatives of this type of nervous system greatly differ even in their appearance. Some of them are extremely reactive, mobile and jovial, i.e., as it were, extremely excitable and alert. Others, on the contrary, are only slightly reac-

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where both cortical processes were weak, and yet the excitatory process prevailed over the inhibitory one.

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 657.

tive, sluggish and self-contained, i.e., in general, so to speak, little susceptible to excitation, inert. Of course, a specific property of the nervous system must conform to this difference in the general behaviour, and this difference may be best accounted for by the mobility of nervous processes."*

This group of animals is characterized by the force of both nervous processes which are fairly well equilibrated or show only a slight predominance of one over the other. The strong and equilibrated animals have been thoroughly investigated and described in detail as a result of the extensive experimentation performed by the Pavlov school (M. K. Petrova, V. V. Yakovleva, V. V. Stroganov, D. I. Soloveychik, M. A. Ussievich, O. P. Yaroslavtseva, I. O. Narbutovich, V. P. Golovina, A. G. Ivanov-Smolensky and others).

Consequently, in the above-mentioned types of higher nervous activity we meet with two extreme unequilibrated types—the weak inhibitable and strong excitable types—and with two intermediate equilibrated strong types—the lively and the quiet ones (or the more active and the more inert types). However, it would be erroneous to think that the diversity of typological variations is confined to these four best investigated types. In his works Pavlov frequently emphasized that the actual number of typological variations was considerably greater and that the problem demanded further thorough investigation.

Present-day literature on the higher nervous activity describes a few cases, mainly observed in Pavlov's lifetime, of transitional, intermediate typological variations which do not fully coincide with any of the previously investigated types of nervous system (V. I. Pavlova, V. P. Golovina, A. A. Lindberg and others).

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* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 657-58.

As is known, I. P. Pavlov was inclined to draw a parallel between his classification of types of nervous systems and the classification of temperaments given by Hippocrates.

"Strong, but unequilibrated animals in which both processes are intense, the excitatory process, however, prevailing over the inhibitory, belong to the excitable, impetuous type, or choleric, according to Hippocrates. Further, strong, quite equilibrated and at the same time inert animals belong to the quiet, slothful type, or, according to Hippocrates' classification, to the phlegmatic temperament. Next come strong, quite equilibrated and at the same time labile animals; they belong to the mobile, active type, or, according to Hippocrates, to the sanguine temperament. And finally, there are animals of a weak type which most of all conform to the melancholic temperament described by Hippocrates; their common and predominant feature is easy susceptibility to inhibition.... Otherwise, this type is less uniform than all others; it embraces diverse animals: those in which the excitatory and inhibitory processes are equally weak; those in which mainly the inhibitory process is extremely weak; fussy animals constantly glancing around and, on the contrary, animals constantly halting, as if becoming rigid. Of course, this diversity is accounted for by the fact that animals of the weak type, like animals of the strong type, differ not only in the force of nervous processes, but also in other features.... A constant and pronounced susceptibility to inhibition disables all these animals alike."*

Pavlov considered that the weak type in all its variations and the lively, sanguine type are the most frequent among dogs; then comes the impetuous, excitable, choleric type; as for the quiet, phlegmatic type, this is rarest among dogs.

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* *Ibid.*, p. 720.

Concluding our brief account of the theory of types of higher nervous activity in animals, we must point out that no substantial alterations or additions have been made to it since Pavlov's death.

3

THE FIRST STAGE IN THE DEVELOPMENT OF THE THEORY OF EXPERIMENTAL NEUROSES

For many years the Pavlov laboratories have been accumulating facts proving that under the influence of difficult experimental tasks placed before the animal's nervous system, and leading to its excessive functional tension, peculiar pathological states arise in the nervous system which, in a certain measure, are connected with the neuro-typological properties of the dogs.

In 1912 M. N. Yerofeeva elaborated in dogs a conditioned alimentary reflex to stimulation of the skin by means of a powerful electric current which, prior to the development of this conditioned reaction, evoked in the dog an unconditioned defensive reflex.

Elaboration of this conditioned connection began with the application of a very weak current as a conditioned stimulus; the current was gradually increased until, finally, it reached extreme tension; nevertheless, instead of an unconditioned defensive reflex this very strong and painful stimulus now produced only a positive alimentary reaction: the animal turned its head towards the place where the food appeared, licked its lips, wagged its tail and displayed a profuse salivary conditioned reflex. Thus the unconditioned defensive stimulus was transformed into a conditioned alimentary signal. The defensive unconditioned reflex was inhibited; instead, an alimentary conditioned reflex was developed,

and it persisted for several months. However, in the course of the next few days, or even within one and the same experimental day, when the electrodes were repeatedly transferred to various points of the skin, the behaviour of the animals abruptly changed. The alimentary conditioned reflexes completely disappeared, and the violent unconditioned defensive reaction to the electric current was fully restored. Moreover, the animals began to manifest general motor excitation in such vigorous forms (never observed in them before) that further experimentation had to be discontinued for a long time. Only in one of the dogs did it prove possible to restore the original state after an interval of three months. The investigation of the higher nervous activity under difficult conditions, carried out in the course of M. N. Yerofeeva's experiments, unexpectedly resulted in the development for the first time of a chronic pathological state which, however, at that time did not attract proper attention.

Similar phenomena were observed later in the experiments conducted by N. R. Schenger-Krestovnikova (1921).* A number of successive, increasingly delicate differentiations between a circle and ellipse were elaborated in a dog. With each new differentiation the form of the ellipse was brought closer and closer to that of a circle, and thus there was obtained an increasingly delicate discrimination between the positive reinforced stimulus (the circle) and the inhibitory (not reinforced) differential stimulus (the ellipse).

When the experimenters used an ellipse the axes of which were 9:8 (i.e., an almost circular ellipse), it proved not only impossible to obtain a complete differentiation, but instead, all previously elaborated differentiations, including the cruder ones, were lost, disinhibited; at the

* This experimental work was started in 1914.

same time the behaviour of the animal underwent an abrupt change: it displayed extreme general motor excitation of a lasting character with destructive tendencies (the dog threw off the experimental apparatus, bit through the rubber tubes, etc.).

"After these experiments," Pavlov stated, "we paid considerable attention to the above-mentioned fact and began to study it experimentally in detail. It became obvious that under certain conditions the clashing of excitation and inhibition led to a disturbance of the usual balance between these two processes, and evoked, in a greater or lesser degree and for a longer or shorter time, a pathological state of the nervous system.... In further experiments dogs were intentionally selected which possessed different types of nervous system, in order to find out the different pathological disturbances in each type of nervous activity which would be produced by functional (i.e., non-surgical) interferences."*

Experimentation along this line was performed in 1922-1923 by M. K. Petrova on two dogs belonging to extreme types of nervous system: one dog was quiet, sedate and inert, showing a certain predominance of inhibition; the other one was very lively, with a definite predominance of excitation. Six conditioned reflexes to different stimuli (acoustic, optical and cutaneous) were simultaneously developed in both animals; the reinforcement (feeding) was added not in 15-30 seconds after the stimulation was begun, but, contrary to the usual practice, in one, two and, finally, three minutes, in order to make all six conditioned reflexes delayed (retarded) for three minutes.

While the first dog coped with this difficult task quite satisfactorily, the second began to display a violent general excitation when the reflexes were delayed for two

* I. P. Pavlov, *Lectures*, p. 256.

minutes; with the further attempt to prolong the delay to three minutes the state of excitation reached peak and was accompanied by a complete disinhibition of all the inhibitory reflexes (delayed for two minutes), acquired with such difficulty. It was necessary to give the animal a long rest, after which by gradually training it to inhibitory (delayed) reactions this problem was, nevertheless, solved: all six reflexes (delayed for three minutes) were elaborated. Now the inhibitory strain in both dogs was considerably increased: the effect of differentiation, conditioned inhibition and extinction was tested on the already existing inhibitory (delayed) reflexes. However, all these tasks were successfully solved and the excitable dog even revealed a high training capacity for inhibitory tasks. Then the experimenter proceeded to accomplish the task already familiar to us—to develop a conditioned alimentary reflex to a strong electric stimulus producing an unconditioned defensive reaction. At first this reflex was developed in both dogs, but with repetition and with the increasing strength of the electric current the entire experimental picture radically changed. In the first dog all elaborated conditioned reflexes disappeared, and naturally, also all the internal inhibitors connected with them; the animal became extremely inert and sleepy. This pathological state made the experimenter discontinue all experiments with the animal for several months. But whereas in the first dog all positive conditioned reflexes disappeared, in the second dog, on the contrary, all previously elaborated inhibitory reactions, which seemed to be quite stable, were disinhibited for a long time, and this again occurred on the background of general motor excitation.

The significance and novelty of these experiments of M. K. Petrova lie in the fact that a painful conflict of the processes of nervous excitation and inhibition in the cerebral cortex, their struggle, or, in Pavlov's terminology,

their "collision," produced in both dogs under similar conditions diametrically opposite results: there took place a nervous breakdown of an excitatory character in one dog—and a nervous breakdown of an inhibitory character in the other.

Concerning these experiments Pavlov wrote:

"Thus, in the two dogs with different types of nervous system, chronic disturbances of the nervous activity, which developed under precisely identical injurious influences, took quite different directions. In the excitable dog the inhibitory process in the cortical cells of the cerebral hemispheres became extremely weakened and almost disappeared. In the quiet dog, usually susceptible to inhibition, it was the excitatory process in the same cells which became extremely weak and almost disappeared. In other words, two quite different types of neurosis were produced."*

For some time after these experiments, the idea prevailed in the Pavlov laboratories that the character of the nervous breakdown, as well as of the experimental neurosis evoked by it, depended mainly on the type of the animal's nervous system. However, as we shall see later, experimental facts obtained in the course of further investigations forced us considerably to revise this notion and to introduce substantial corrections.

In the quiet, somewhat inhibitable dog, described by M. K. Petrova in her experiments, a rest of several months after complete discontinuance of the experiments, resulted in full rehabilitation of the conditioned reflexes. But in the excitable dog rest alone proved insufficient; restoration of all the lost internal inhibitors could be accomplished only by giving bromides for ten days (by rectal injections of 100 cubic cms. of 2% solution of potassium bromide daily), which produced a stable effect.

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* I. P. Pavlov, *Lectures*. p. 261.

In 1922-1923 O. S. Rosenthal, like M. K. Petrova, met with phenomena of nervous breakdown. In a quiet, inert dog with a certain predominance of the inhibitory process he elaborated a differentiation, never applied before, between two skin stimuli (by means of special apparatus for tactile stimulation), which presented rhythmic contacts with one and the same skin area.

The rate of twelve such contacts in thirty seconds served as a positive (reinforced) stimulus and the rate of thirty contacts in thirty seconds served as an inhibitory (not reinforced) stimulus. The elaboration of this differentiation was obtained with great difficulty. When, however, O. S. Rosenthal repeatedly attempted to apply the positive stimulus in about half a minute, and then also immediately after the application of the inhibitory stimulus, all conditioned reflexes in the dog vanished, and there developed an irresistible state of drowsiness; this lasted for several months. Thus, the difficult task of balancing the excitatory and inhibitory processes during elaboration of a differentiation of an extraordinary kind, and especially when a quick interchange of both processes was required, led to a nervous breakdown of an inhibitory character and to the development of experimental neurosis.

In 1923 E. M. Kreps obtained in a dog belonging to the weak inhibitable type of nervous system a definite and lasting breakdown of an inhibitory character exclusively by elaborating a differentiation between two rhythms of mechanical skin stimulation (the positive stimulus being twelve contacts and the inhibitory stimulus—twenty-four contacts with the skin in thirty seconds). In the same year I. P. Razenkov observed a persistent inhibitory neurosis induced by him (and afterwards frequently repeated) as a result of a single direct transition from an inhibitory to an excitatory stimulus, the former being twelve light pricks and the latter—twen-

ty-four light pricks in thirty seconds.* Simultaneously V. V. Siryatsky and E. M. Kreps succeeded in obtaining a nervous breakdown of an inhibitory character in the course of elaborating comparatively simple differentiations: in the first case—between two tones, and in the second case—between two metronomic rhythms (here, too, the inhibitory neurosis was eliminated by giving bromides).

Of considerable interest and novelty was the experimental work performed by V. V. Rickman at the beginning of 1924. Rickman set himself the task of studying the action of unusual or extraordinarily intense functional influences upon the dog's higher nervous activity. Experiments were carried out with an animal manifestly belonging to the inhibitory type of nervous system. The following stimuli were simultaneously applied to exert such unusual and intense functional influence upon the nervous system: 1) a loud rhythmic crackle produced by a rattle and resembling the crackle of gun-fire; 2) a sudden emergence in front of the dog of an unusual figure in a mask and fur coat turned inside out; 3) an explosion of powder near the stand; 4) a special swinging platform mounted on the stand and on which the dog was placed. All these stimuli, as mentioned above, were applied simultaneously in the space of forty-five seconds. At the very beginning the animal started, rushed forward, instantaneously rose on its hind legs, set its forelegs against the food receptacle which was before its muzzle and became rigid, its limbs extended, its head thrown back, its eyes wide open, the whole musculature strained and the breath deranged. Such a state of stiffness, which V. V. Rickman compares with a state of

* Subsequently we shall revert to this experimental work of I. P. Razenkov who has considerably advanced the theory of experimental neurosis.

decerebrate rigidity and which he attributes to general inhibition suddenly arising in the cortex and rapidly irradiating as far as the mid-brain, lasted about one minute and was disturbed by a strong acoustic conditioned stimulus (a tone) which provoked in the animal chaotic motor excitation.

This state was observed during the whole period of the experiment; it was weaker in the intervals between the conditioned stimuli and more intense under the action of each stimulus, as well as of other, outside stimuli. It was accompanied by the disappearance not only of all artificial but also of all natural alimentary conditioned reflexes. Moreover, even the unconditioned reflex proved to be inhibited. The overwhelming predominance of inhibition in the higher parts of the nervous system persisted for a period of more than two weeks, showing slight fluctuations. Only sixteen days later was it possible to restore the dog's higher nervous activity.

However, as soon as the swinging platform was again mounted on the stand, i.e., as soon as one of the components which had caused the inhibitory breakdown was again introduced, the conditioned reflexes vanished anew and the pathological disturbances reappeared on the background of general motor excitation. Recovery could be attained only when, a week later, the platform was removed. It is interesting to note that the picture of the neurosis was fully reproduced as if by the mechanism of conditioned reaction to one of the components of the initial pathogenic situation.

Whereas this particular neurosis and its reproduction were artificially obtained in the course of experimental investigations in laboratory conditions, four to five months later the same animal manifested a similar pathological state which this time emerged and developed under natural, although unusual and extraordinary, conditions.

This opportunity was afforded by an exceptional natural calamity—the memorable flood which occurred in Leningrad on September 23, 1924. During a terrific storm, with the wind at times reaching hurricane force and turning up trees by the roots, the kennels were flooded and the dogs had to be rescued and moved to the upper floors of the laboratory. Among the dogs was the one just described. Whereas during the first days after the flood most of the dogs did not display any deviation from the normal in their general behaviour and in the course of the experiments, V. V. Rickman's dog manifested again a pronounced breakdown of an inhibitory character, this time a very persistent inhibitory neurosis. A considerably heightened susceptibility of the cortical cells to inhibition stood out with special prominence. The rehabilitation of the positive conditioned connections was accelerated now by allowing an interval of few days in the experimental work, now by shortening the isolated action of the conditioned stimuli, or by a general alleviation of the experimental procedure.

However, upon a single administration of any inhibitory stimulus (for example, the differential one), all positive reflexes disappeared and the dog began persistently to decline food. Only eight months after the flood was it possible to speak about a return to normal.

A no less striking and exquisite case of a nervous breakdown of an inhibitory character, which resulted in the development of a durable pathological state, was simultaneously observed by A. D. Speransky in a dog also obviously belonging to the inhibitory type of the higher nervous activity.

When the dog was placed in the experimental stand about one week after the flood it displayed unusual motor excitation; all previously elaborated conditioned connections were practically absent and it stubbornly rejected food, even turning its head away from it. This state per-

sisted for several days. During the next three days the dog was purposely left without food, but this did not increase its alimentary excitability and did not improve the situation. Although subsequently the conditioned reflexes appeared from time to time, they proved to be very unstable, manifesting themselves only in the presence of the experimenter and completely disappearing the moment he left the room. The application of the strongest conditioned stimulus (a bell) immediately resulted in transmarginal inhibition (owing to the considerably increased susceptibility of the animal's cortical cells to inhibition) and for a long time washed away the conditioned connections which had already appeared.

Only about two months after the flood were normal relations within the cortex restored. Then the following experiment was made: a stream of water was allowed to trickle through a wide rubber tube beneath the door of the room where the dog was kept in its usual stand. The water formed a small pool on the stone floor. The dog jumped up quickly, and gazing restlessly at the trickling water began to plunge backwards and forward, breathing heavily the while. All alimentary conditioned reflexes, both artificial and natural, disappeared at once, and it began to reject food.

Thus, the reproduction of a situation somewhat resembling the picture of the flood immediately evoked a new breakdown with the resulting pathological state; this convincingly proved that the first nervous breakdown in the given dog had been really caused by the flood.

As we have seen, in the first stage of the study of pathological disturbances in the higher nervous activity, provoked by noxious influences of a functional character, investigation was centred on two principal forms of nervous breakdown and, at the same time, on two principal forms of experimental neurosis, and similar pathological states caused by unusual and noxious influences of the

external environment under natural (non-experimental) conditions.

Cases were investigated where the nature of pathological reactions to difficult experimental tasks or to perilous situations were to a considerable degree accounted for by the specific properties of the type of nervous system. At that stage of investigation it seemed that the unbalanced character of the type of higher nervous activity (the excitable or inhibitable types) was an indispensable pre-condition for the development of such pathological disturbances.

Utterly indisputable in this respect are the following words of Pavlov: "Our experiments and observations bring out that a chronic pathological state of the cerebral hemispheres can occur from either of the two causes: first, a conflict, a collision between excitation and inhibition, which the cortex finds itself unable to resolve; second, the action of powerful and unusual stimuli."*

4

PHASIC CHANGES OF THE CORTICAL ACTIVITY OR INTERMEDIATE STATES BETWEEN WAKEFULNESS AND SLEEP

When in the course of experimentation a state of sleep was developed in dogs under the prolonged action of weak and monotonous stimuli, under the influence of internal inhibitory agents repeatedly applied during one and the same experiment, or as a result of the dog's long stay in the stand in a state of peace, rest and absence of any conditioned stimuli, it proved possible to observe in some animals a number of transitional or intermediate states (phases) between wakefulness and sleep.

* I. P. Pavlov, *Lectures*, p. 277.

For example, when general sleep inhibition irradiated from the cortex to the centres of the brain stem, in some cases there were observed phenomena of waxy rigidity, i.e., of catalepsy, which testified to the liberation, temporary disinhibition of the statotonic unconditioned reflexes, equilibrating the body in space. With the intensification of inhibition this state was superseded by a general relaxation of the muscles and by a deep sleep (N. A. Rozhansky, M. K. Petrova and others). In cases when the general sleep inhibition, while embracing the motor area of the cortex, did not yet affect other cortical areas, it was possible to develop salivary conditioned reflexes to auditory, visual and other stimuli; however, the conditioned motor reaction proved to be inhibited, the dog reacting neither to artificial nor to natural conditioned stimuli and taking no food. There took place, as it were, a dissociation of the secretory and motor conditioned reactions (L. N. Voskresensky, V. V. Rickman, A. D. Speransky and others).

Thus, here it is question of transitional, intermediate phases between sleep and wakefulness, differing in the extensity of sleep inhibition, which gradually embraces larger and larger areas of the cortex, and then spreads lower and lower to the system of somato-motor centres of the brain stem.

In some cases of nervous breakdown of an inhibitory character with the resulting phenomena of inhibitory neurosis there was observed, as it were, a persistence or frequent recurrence of one of such transitional, intermediate states in the animal (M. K. Petrova, V. V. Rickman, V. P. Golovina, F. P. Mayorov, O. P. Yaroslavtseva and others).

However, besides the above described states which differ, as already mentioned, in the extensity of sleep inhibition, the Pavlov school investigated intermediate states between wakefulness and sleep, special phasic

states characterized by peculiar changes in the interrelations between the excitatory and inhibitory processes, changes which are expressed in derangement of the "force correlations" between conditioned stimuli of different intensity and respective conditioned reactions to them.

These phenomena in the cerebral cortex were first distinctly observed, studied and described by I. P. Razenkov in his work already mentioned above (1923-1924). In the course of one of his experiments he applied a quick, direct transition from an inhibitory stimulus (tactile stimulation of the skin at the rate of twelve contacts in thirty seconds) to a positive stimulus (the same stimulation at the rate of twenty-four contacts in thirty seconds); one day later he observed in the dog a nervous breakdown of an inhibitory character; during the next ten days all conditioned reflexes fully, or almost fully, disappeared. However, after that he encountered quite new and unexpected phenomena: during the next two weeks strong stimuli practically did not evoke any secretory effect, whereas weak stimuli paradoxically produced the maximum effect.

This situation was followed by another which lasted for a whole week: all conditioned stimuli, both the strong and the weak ones, became, in respect of effect, absolutely equal, evoking conditioned reactions of equal size.

Then a new period set in; it also lasted seven days, and in the course of it the maximum effect was produced by medium conditioned stimuli; as for the weak and strong stimuli they produced either an insignificant effect or did not evoke any conditioned reaction at all. After this stage the higher nervous activity of the dog returned to normal, and the usual dependence of the size of conditioned reflexes on the strength of the applied conditioned stimuli was restored.

N. E. Wedensky, distinguished Russian physiologist, at one time investigated the phenomena of parabiotic

inhibition (first established by him) in the peripherical nerve fibre, which is caused by various factors, including the action of different pharmacological substances, especially narcotics; he described three successive stages in the development of these phenomena: a) the provisory stage, when the effects of strong and weak stimuli became equal; b) the paradoxical stage, when the weak stimuli produced a greater effect than the strong ones; c) the inhibitory stage, when neither stimuli produced any effect.

Subsequently, when the parabiosis was at its height, the nerve fibre lost its excitability and conductivity.

When, after the termination of the narcosis, the functions of the nerve fibre were restored, all the above-described stages developed in reverse order.

The similarity of the experimental facts obtained by N. E. Wedensky from his study of the nerve fibre, on the one hand, and of the facts relating to the activity of the cortex, established by I. P. Razenkov, on the other hand, is, of course, beyond doubt. I. P. Razenkov considers them absolutely analogous, although he, at the same time, points out certain differences, and in particular the fact that the last stage (where the maximum effect is produced by medium stimuli) did not appear in N. E. Wedensky's experiments at all.

Commenting on the above-described functional deviations in the activity of the cerebral cortex, Pavlov said: "Study of these deviations in the direction of the preponderance of the inhibitory process and the weakening of the excitatory, has convinced us that one of the discoveries made by our late, distinguished physiologist N. E. Wedensky, is profoundly correct."*

So, observing the disturbances of the cortical activity which result from difficult experiments and the ensu-

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 414-15.

ing nervous breakdown of an inhibitory character, I. P. Razenkov was able to establish the following stages or phases: 1) the *inhibitory phase* which is characterized by complete or almost complete disappearance of conditioned connections; 2) the *paradoxical phase*, when weak stimuli produced the strongest effect and strong stimuli—the weakest; 3) the *phase of equalization*, when all conditioned stimuli, irrespective of their strength, produced equal effects; 4) the so-called *phase of medium stimuli*, when the strongest effect was produced by stimuli of medium strength.

While the first three phases were later repeatedly observed and confirmed by other research workers, the last phase, i.e., the phase of medium stimuli, has until now been observed only by few investigators (V. V. Rickman, O. S. Rosenthal, P. O. Makarov) either because of its impermanence, or because of its fleeting character.

If after the first application of the difficult experimental task the phasic changes discovered by I. P. Razenkov in all lasted five weeks, after the second application they lasted only about ten days, after the third only four days and after the fourth they were not observed at all. Thus, the experiments revealed a high training capacity of the given nervous system for adapting itself to the difficult experimental task.

The equalization and paradoxical phases in experimental neuroses, to say nothing of the inhibitory phase, were subsequently described by the comprehensive research of the Pavlov laboratories (M. K. Petrova, V. V. Rickman, M. A. Ussievich, N. V. Zimkin, O. S. Rosenthal, D. T. Kuimov, O. P. Yaroslavtseva, F. P. Mayorov, I. O. Narbutovich, A. I. Skovoroda-Zachinyaev and others). The emergence of similar phasic states, but having a fleeting character and lasting only a few minutes, could also be observed in some dogs during the period of their falling asleep and waking up in cases of natural

and normal sleep; this convincingly proved that these phases actually are transitional, intermediate states between wakefulness and sleep (B. N. Bierman, O. S. Rosenthal, N. V. Zimkin and others). Thus, the phenomena, which here lasted only a few minutes, persisted for days and even weeks and months in the case of experimental neuroses.*

As far back as 1910, Shishlo registered the following interesting fact. When the experimental dog was falling into drowsiness as a result of the application of thermal (heat) conditioned stimuli, Shishlo observed a state when the positive conditioned stimuli practically had no effect, and the inhibitory one, on the contrary, became definitely positive, i.e., the positive conditioned stimuli disappeared whereas the inhibitory ones were disinhibited.

This state, later called by Pavlov the *ultra-paradoxical phase*, was also frequently observed in cases of breakdowns of an inhibitory character and in the course of inhibitory experimental neuroses (M. K. Petrova, A. G. Ivanov-Smolensky, I. P. Razenkov, V. V. Rickman, I. N. Zhuravlev, E. A. Asratyan, O. P. Yaroslavtseva, L. V. Vassilieva, O. S. Rosenthal and others); it was investigated with painstaking thoroughness by L. O. Seewald and M. K. Petrova.

Under the action of narcotics (chloral hydrate, urethane) there was observed a gradual extinction of the conditioned reflexes first to weak conditioned stimuli, then to medium, and finally to strong ones (S. I. Lebedinskaya). This state was called the *narcotic phase*; it was observed in cases of certain chronic pathological disturbances of an inhibitory character caused by a durable exhaustion of the cortical cells (A. D. Speransky);

* The distortions of the "force correlations" between conditioned stimuli have been recently investigated in detail by A. I. Makarichev.

it was also observed in cases of experimental neuroses (V. V. Yakovleva, O. S. Rosenthal, O. P. Yaroslavtseva and others).

In 1936 O. S. Rosenthal evoked general inhibition in the dog's cortex by a frequently repeated application of considerably delayed conditioned reflexes; during these experiments he investigated the gradual transition from one intermediate state to another and tried to establish, so to speak, the "succession of phases," a certain sequence, and regularity in their development. As a result of these experiments O. S. Rosenthal elaborated the following scheme: 1) the normal state of the cerebral cortex; 2) a state transitory to the phase of equalization; 3) the phase of equalization; 4) a state transitory to the narcotic phase; 5) the narcotic phase; 6) the paradoxical phase; 7) the inhibitory phase. However, it should be stressed that the sequence of the phasic states may greatly vary.*

Transitional phases between wakefulness and sleep, according to Pavlov, represent different degrees of the extensity and intensity of the inhibitory process in the cerebral hemispheres, but, of course, they also differ qualitatively.

Since the intermediate states between sleep and wakefulness are particularly manifest in the development of hypnotic sleep, Pavlov called them also hypnotic phases.

"There is no doubt," he said, "that inhibition, while irradiating and deepening, develops different degrees of

* The equalization and paradoxical phases may be observed not only when the conditioned reflexes are of a small size (phasic states at the lower limit), but also when they are at a high level (the upper limit), which first was established by V. V. Rickman. The same applies to the ultra-paradoxical phase (it was first observed at a high level in our experiments). The relation between this phase and other phases, as well as the role of this phase among others have not yet been defined. Pavlov regarded it as a pathological distortion of relations of induction.

a hypnotic state, and that spreading from the cerebral hemispheres downward to the utmost over the brain, it produces normal sleep. The diversity and multiplicity of hypnotic stages, which at first can hardly be distinguished from the waking state, strikingly manifest themselves even in our dogs. In respect of the intensity of inhibition the so-called equalization, paradoxical and ultra-paradoxical phases are worth mentioning.... In respect of the extensity of inhibition there are observed functional dissociations in the cortex, as well as between it and the lower parts of the brain. The motor area of the cortex is particularly often isolated from other areas, and even in this area sometimes a dissociation of functions comes to the fore."*

5

THE FURTHER DEVELOPMENT OF THE THEORY OF PATHOLOGICAL CHANGES IN THE HIGHER NERVOUS ACTIVITY CAUSED BY FUNCTIONAL INFLUENCES

Further research into the collisions between the nervous processes of excitation and inhibition, nervous breakdowns of an inhibitory and excitatory character, and experimental neurosis was, above all, directed to the investigation of the various situations causing these phenomena; this was of great significance for disclosing the major pathogenic mechanisms which govern the pathological deviations of the higher nervous activity resulting from nervous breakdown.

These situations included: the administration of ultra-powerful stimuli (M. K. Petrova, I. O. Narbutovich, and others); the elaboration of excessively delicate or numer-

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 608-09.

ous differentiations (O. S. Rosenthal, F. P. Mayorov, *V. P. Golovina, G. V. Skipin, O. P. Yaroslavtseva* and others); a considerable prolongation of a differential stimulus (V. V. Yakovleva, I. O. Narbutovich); the elaboration of difficult differentiations between complex, synthetic stimuli (A. G. Ivanov-Smolensky, M. N. Yurman, A. M. Zimkina); the elaboration of a conditioned response to every fourth successive stimulus (M. A. Ussievich); a quick, direct transition from an inhibitive stimulus to a positive one, already mentioned above (V. V. Stroganov, M. K. Petrova, D. I. Soloveychik, I. O. Narbutovich and others), and finally, the reshaping of the dynamic stereotype which increasingly attracted the attention of the researchers. This was accomplished in the following way: an abrupt change of the accustomed order was made in the system of positive and inhibitory conditioned reflexes, which had been repeated and trained from day to day under one and the same stereotype sequence of stimuli and intervals between them; sometimes, it was a change in the sequence of stimuli, sometimes a change in the duration of the intervals between them; in some cases it was a full reshaping of the stereotype, and in some—an alteration of individual stimuli only, more often conjugated ones (D. I. Soloveychik, I. O. Narbutovich, M. A. Ussievich, V. V. Yakovleva, D. T. Kuimov, T. A. Timofeyeva and others). In many cases this resulted in nervous breakdowns.

Comparing all the situations, which proved difficult for the dogs' nervous systems and which led to pathological deviations of the higher nervous processes—to experimental neuroses, Pavlov (in 1935) came to the conclusion that these situations could be divided into the following three major groups:

a) overstrain of the excitatory process (under the action of external agents of a great, extraordinary, unu-

sual force, which, for instance, we have seen in the works of V. V. Rickman and A. D. Speransky);

b) overstrain of the inhibitory process (as, for example, observed in the already described experiments of M. K. Petrova, and usually taking place under any inhibitory overburdening of the nervous system as a result of numerous, too delicate and complex and protracted differentiations or other inhibitors);

c) overstrain of the mobility of the nervous processes (and, above all, the direct transition from the inhibitory to the positive stimulus, as well as various reshaping of the dynamic stereotypes).

"Nervous activity, as all physicians know," Pavlov wrote, "consists of two mechanisms, two processes: excitatory and inhibitory. Now with regard to these two processes we distinguish three fundamental moments, namely, the force of these nervous processes, both excitatory and inhibitory, the mobility of these processes—inertness or lability, and finally, the equilibrium between these processes.

"Certainly, the normal course of these processes, which are of such nature, determines the whole of the normal higher nervous activity, or, by applying the usual terminology—psychical activity—not only of animals but also of man....

"All these processes with their basic properties can be diverted from their usual tendencies and caused to become pathological. For this purpose we make use of strictly definite measures. There are three such measures: overstrain of the excitatory process, overstrain of the inhibitory process, and overstrain of the mobility of the nervous processes."*

It is noteworthy—and this has been observed by many investigators—that the phenomena of a nervous break-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 681.

down and the consequent development of pathological disturbances of the higher nervous activity often do not take place immediately after the administration of the critical difficult task, or after the overstrain of the higher nervous processes evoked by it, but some time later, for instance, after a delay of one or two days (M. K. Petrova, V. V. Rickman, D. I. Soloveychik, V. V. Yakovleva, O. P. Yaroslavtseva, A. G. Ivanov-Smolensky and others).

There is a special group of chronic disturbances of the higher nervous activity which develop, so to say, leisurely, are not connected with any definite and obviously difficult task and, consequently, do not have the character of an acute nervous breakdown.

In some cases, usually after long and uninterrupted laboratory work with one and the same conditioned stimuli (during a period lasting from two to four years and more), all conditioned reflexes began gradually to fade away and vanish without any obvious reason; at the same time it proved quite possible to develop reflexes to new conditioned stimuli never applied before; sometimes the conditioned connections did not fully disappear, but, being often repeated, began to manifest either an unusually rapid exhaustibility, a predisposition to inhibition, or a development of persistent phasic states which did not disappear unless a long rest was provided. In other cases, after many years of laboratory work there was observed a weakening of processes of internal inhibition (N. A. Podkopayev, D. A. Biryukov, I. N. Zhuravlev, A. D. Speransky, O. P. Yaroslavtseva, I. O. Narbutovich and others). Consequently, the common feature characteristic of this group was the development of lingering, chronic disturbances of the higher nervous activity which very much resembled experimental neuroses, but were not connected with collisions of the nervous processes or caused by acute nervous breakdowns.

Almost in all such cases the disturbances of the cortical dynamics proved to be fully reversible after a long rest, and particularly after the replacement of the old conditioned stimuli by new ones. It would be absolutely wrong to regard these cases from the point of view of the wear or disablement of the cortical cells. In reality, under the influence of long, uninterrupted and monotonous work there takes place a chronic but reversible exhaustion of these cortical cells accompanied by a slow and gradual decline of the functional limit of their working capacity and by the development of phenomena of stable and persistent transmarginal inhibition.

Similarly, the chronic weakening of internal inhibition appears to be reversible as a result of rest, replacement of stimuli and gradual training.

It seems to us that in the long run the described chronic disturbances of the higher nervous activity very much resemble experimental neuroses, but here the difficult task does not have the character of a suddenly emerging situation, and the overstrain of the higher nervous processes develops slowly and gradually.

While in the first case we meet, as it were, with a rough model of an acute psychical trauma, in the second case we have a model of a chronic psychical trauma, or of durable and persistent psychical overstrain.

As we already know, in the first stage of the study of experimental neuroses it seemed that nervous breakdowns were exclusively, or at least as a rule, inherent in the unequilibrated types of nervous systems.

As a matter of fact individual characteristics of a number of animals, which could be considered as model representatives of the strong and equilibrated type, at first seemed to prove this point of view (M. K. Petrova, V. V. Stroganov, I. O. Narbutovich, O. P. Yaroslavtseva, D. I. Soloveychik and others). It is true that under the action of collisions between the excitatory and inhibitory

processes certain fluctuations of the higher nervous activity were observed in these dogs, but they were insignificant, fleeting, and more often did not overstep the bounds of the analyser in which the collision was developed. In one case thirteen such collisions were produced (I. O. Narbutovich), in another—about twenty (V. V. Stroganov), in a third—thirty (M. K. Petrova) and in a fourth—thirty-nine (O. P. Yaroslavtseva); nevertheless, no real nervous breakdowns or experimental neuroses could be obtained.

However, a number of further investigations convincingly proved that when the difficult tasks are specially selected, varied and persistently repeated, nervous breakdowns and strongly pronounced experimental neuroses also occur in representatives of the equilibrated strong types of higher nervous activity (M. K. Petrova, I. O. Narbutovich, V. V. Yakovleva, V. P. Golovina, O P. Yaroslavtseva and others). Basing himself on these experimental facts Pavlov stated: "In well equilibrated and strong animals, i.e., those in which both the excitatory and inhibitory processes stand on the same level and whose mobility is likewise normal, it is certainly also possible to produce a nervous disease. But that takes considerable time and labour because different means must be tried, while in excitable and in weak animals it is very easily attained."*

As we already know, in the first stage of the study of nervous breakdowns it was believed that breakdowns of an excitatory character are peculiar only to the excitable type, and breakdowns of an inhibitory character—only to the weak inhibitable type. But further investigations refuted this supposition too. It proved that both kinds of breakdowns can be obtained also in representatives of the strong, equilibrated type. Moreover, it was

* I. P. Pavlov, *Twenty years of Objective Study*, p. 685.

found that breakdowns not only of an excitatory but also of an inhibitory character are possible in representatives of the excitable, i.e., unequilibrated type (V. V. Yakovleva, I. O. Narbutovich, O. P. Yaroslavtseva, F. P. Mayorov and others). Thus, the dependence of the character of breakdown on a certain type of nervous system must be considered as highly relative: although breakdowns of an inhibitory character are met with more frequently in animals belonging to the weak, inhibitable type, and breakdowns of an excitatory character are most pronounced in dogs of the strong, excitable type, both kinds of breakdown may be also observed in the other types of higher nervous activity (in the strong, equilibrated types, as well as in the unequilibrated ones).

There are reasons to believe that the character of nervous breakdown depends on a combination and interaction of many factors; besides the fundamental properties of the given type, they include: the peculiarities of the situation which caused the breakdown; the character and sequence of the difficult tasks placed before the animal, its previous life experience, the state of its somatic health, age features, etc. The process of ageing by itself, for example, considerably changes animals' cortical dynamics and consequently determines their specific reaction to the difficult tasks (A. V. Tonkikh, L. A. Andreyev, D. I. Soloveychik, M. K. Petrova, M. A. Ussievich, V. V. Yakovleva, A. M. Pavlova, N. A. Podkopayev and others). The same applies to the state of pregnancy (D. S. Fursikov, O. S. Rosenthal, I. R. Prorokov and others). A considerably heightened alimentary excitation evoked by keen hunger drastically changes the cortical dynamics and leads to phasic states on the upper level (V. V. Rickman, M. K. Petrova, D. I. Soloveychik and others). Pronounced phasic states also arise in dogs as a result of sexual excitation (M. M. Gubergritz, F. P. Mayorov, S. N. Virzhikovsky,

V. I. Pavlova).* Finally, considerable and steadily growing disturbances of the higher nervous activity in animals can also be observed as a result of chronic starvation (Y. P. Frolov, O. S. Rosenthal).

All the above-mentioned instances quite clearly show that the susceptibility of dogs to nervous breakdowns of one or another character does not depend exclusively on the type of nervous system. Later we shall meet with other similar instances.

In the first stage of the study of experimental neuroses only two syndromes were known: on the one hand, a sharp diminution or full disappearance of positive conditioned reflexes (the inhibitory syndrome), and, on the other hand, a general disinhibition, a loss of all previously acquired inhibitors (the syndrome of predominant excitation and disinhibition). But when the phasic states had been studied and described, the picture considerably changed. The diversity of syndromes observed under experimental neuroses became quite considerable, tending towards further differentiation.

The picture of neurosis with a predominant excitatory process was complicated by the fact that along with general motor excitation, very often having an active-defensive character and accompanied by destructive tendencies and the disinhibition of internal inhibitors (differentiations, conditioned inhibitors), there were observed phasic phenomena on the upper level, and particularly, the ultra-paradoxical phase (I. O. Narbutovich, V. V. Yakovleva, M. A. Ussievich). Thus it turned out that breakdowns of an excitatory character may simultaneously be, in a certain measure, breakdowns of an inhibitory character, producing a picture of a mixed neurosis, where phenomena of predominant excitation and

* Quoted from F. P. Mayorov's book *The History of the Theory of Conditioned Reflexes*, U.S.S.R. Academy of Medical Sciences, 1948, pp. 128-29 and 280-81.

disinhibition develop side by side with intermediate states between wakefulness and sleep (phasic states, or, according to Pavlov's terminology, hypnotic phases).

As to inhibitory neuroses, here the diversity and the pronounced character of phasic states, as well as the dynamics of their succession, produce a much more differentiated, complex and changeable picture than that observed under excitatory neuroses. Somewhat anticipating our account we shall point out in passing that not infrequently inhibitory neuroses, too, are actually mixed neuroses, since distinct and stable intermediate states between sleep and wakefulness (according to Pavlov's terminology, different stages of diffused inhibition)* are often combined here with phenomena of general motor excitation (rather of a passive-defensive character).

Consequently, the line of demarcation, which had been originally drawn between excitatory and inhibitory neuroses, was to a considerable degree obliterated, for which one more factor was responsible.

A thorough and profound study of various typological variations in dogs showed that in a number of cases, when the cortical processes are overstrained, there takes place a direct and immediate transition from highly predominant excitation to manifestly predominant inhibition and to phasic states (I. O. Narbutovich, F. P. Mayorov and others). It also proved possible more than once to observe repeated fluctuations and changes in the cortical dynamics, now of an excitatory, now of an inhibitory character, which were sometimes interchanged with states of relative equilibrium of both nervous processes. These observations introduced into laboratory practice new concepts of circular neuroses, or cyclical neurotic states (M. K. Petrova, V. V. Yakovleva, I. O. Narbutovich, O. P. Yaroslavtseva, L. V. Vassilieva, O. S. Rosenthal and others).

* I. P. Pavlov, *Lectures*, p. 235.

The study of the *mobility* of cortical processes, which were started in the Pavlov laboratories a few years before his death, opened up wide prospects for the pathophysiology of the higher nervous activity. However, morbid derangements of mobility both in the shape of pathological inertness and in the shape of pathological lability of nervous processes, which undoubtedly are quite often observed under experimental neuroses, unfortunately remain up to now little investigated. Later we shall discuss these problems in greater detail.

In some dogs, along with a very rapid development of conditioned reactions to stimuli and their considerable size, there was observed a quick exhaustion of these reactions. In these cases the conditioned reflexes were, so to speak, of an explosive character. This disturbance of the excitatory process, resembling the phenomena of excitatory weakness, was regarded by Pavlov as a manifestation of the pathological lability of nervous excitation.

By overstraining the inhibitory process in dogs (mainly by protracting the differentiations) M. K. Petrova obtained a pronounced instability of this process, or its pathological mobility: now phenomena of disinhibition could be observed, now the ultra-paradoxical phase, now circular, cyclical fluctuations. Under these conditions various phobias developed in the dogs and especially a strong phobia of depth.

These phobias (pathological passive-defensive reactions) revealed peculiar stagnation, inertness and resistance to treatment. M. K. Petrova succeeded in experimentally proving that when there arises pathological mobility of the inhibitory process (of internal inhibition), the "fears" once experienced by the animal, its passive-defensive reactions, for some reason or other impressed in its previous experience, tend to be disinhibited. With the elimination of the pathological disturbances of the

inhibitory process, all phobias usually disappeared. The phenomena of inertness of the excitatory or inhibitory processes manifested themselves in the phobias, depending on the nature of the latter. However, we must repeat that the disturbances of the mobility of cortical processes under experimental neuroses remain little investigated.

In the cases just described and frequently in the previously described disturbances in dogs the following fact stands out in bold relief: the experimentally induced disturbances of the higher nervous activity are not confined to the narrow bounds of laboratory experience, but usually extend, in a greater or lesser measure, to the general behaviour of the animals not only in the experimental stand but also under natural conditions.

"The neurotic state," Pavlov said, "is expressed in the fact that the animal does not properly respond to the conditions in which it is placed. This refers to laboratory characteristics as well as to its general conduct. Concerning the latter, everyone will agree that such a dog, having earlier been well, has since become ill.... The disturbed nervous equilibrium is clearly observed not only by us in the system of conditioned reflexes, our attendants also notice it. To them the dog is submissive. It had been trained to be orderly and knew where to go when led to experimentation. Now everything abruptly changed. The attendants simply say that the dog has become stupid or even mad. The pictures of the neurosis in animals that became ill are sufficiently varied."*

First of all a considerable difference in the behaviour of the animals is observed already at the moment when the critical "breakdown" situation (collision) is applied, at the moment of acute overstrain of the nervous system. Let us recall, for example, the reaction of V. V. Rick-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 686.

man's dog to the emergence of a sudden, unusual and super-powerful terrific situation, a reaction which took the shape of general stupor with a wide irradiation of inhibition not only over the cortex, but also over the lower parts of the brain; V. V. Rickman maintains that this reaction resembles the state of decerebrate rigidity. At the moment of collision one of the experimental dogs of M. K. Petrova "stood like a graven image, like a statue." Not infrequently under these conditions the dogs abruptly turn away from the stimulating agent, or from the food receptacle, at the same time howling or moaning. Sometimes they begin to plunge about the stand, and even fall into a state of rage (more often animals belonging to the excitatory type); they tear off the bulbs for collecting the saliva, bite through the rubber tubes and the leashes. If the animal is trained to move freely in the stand, the application of a breakdown situation (collision) may impel it to a swift, even instantaneous flight from the stand (for example, in the experiments of A. G. Ivanov-Smolensky and also of M. A. Ussievich).

Evidently the peculiarities of the reaction in each individual case depend on the type of nervous system, the character of the difficult task, the physiological (nervous and somatic) state of the animal, its age, etc.

Equally diverse are the durable and chronic changes in the behaviour of dogs observed during more or less protracted pathological states caused by functional influences overstraining the nervous systems of the animals.

On the one hand, there frequently develops a state of limpness and drowsiness which often manifests itself not only when the dog is in the stand, but also when it is in its natural environment. Under such conditions there are observed (mostly when the dog is in the stand) transitional, intermediate states between wakefulness and sleep already familiar to us, and particularly, those

which were regarded by Pavlov as different degrees of extensity of diffused inhibition in the brain. Among them are: more or less protracted states of waxy rigidity, or catalepsy; catatonia-like (stuporous) states (according to the terminology of M. K. Petrova—"abortive catatonia"); states of general strained torpor accompanied by the dissociation of the motor and secretory components of the conditioned reaction, of which the first proves to be inhibited; states of negativism accompanied by a persistent rejection of food; and finally, states of general muscular relaxation, when the dog hangs limply in the loops and snores.

On the other hand, the changes in the dog's behaviour which are retained long after the nervous breakdown, as we have already seen, may have quite a different character. Phenomena of general motor excitation are most frequently encountered; sometimes they are followed by refusal of food, by whining, howling, moaning, sighing, and often by shortness of breath or by abundant salivation. All these phenomena manifest themselves with particular force when the dog is in the stand; usually they become more intense under the action of conditioned stimuli (particularly of strong and inhibitory stimuli) and become weaker during the intervals.

At present it is difficult fully to explain the nervous mechanisms governing such phenomena; these mechanisms must still be sought. But there are reasons to believe that a substantial role is played here by phenomena of positive induction: more or less profound inhibition of positive alimentary reactions causes the disinhibition and intensification of the antagonistic, negative, defensive reactions.

A somewhat different picture was observed by us in one of our experimental dogs as far back as October 1923. This was a lively, active and affectionate young male dog attached to his master; he was closest to the strong,

equilibrated, although somewhat excitable type. After a nervous breakdown induced in this animal by a differentiation between two complex, synthetic stimuli, which presented for him a task of the utmost difficulty, his behaviour suddenly and abruptly changed. Previously, as soon as the cage had been opened, the dog would rush as fast as he could to the laboratory and, leaving his master behind, would jump up on to the stand. Simple conditioned reflexes and inhibitory reactions had been rapidly and firmly developed in this dog; he would always take food with avidity.

After the breakdown the dog, at the sight of the experimenter, hid himself in the farthest corner of the cage; it was necessary, therefore, to drag him to the laboratory, overcoming his silent but stubborn resistance; at best he sluggishly trudged behind his master. Being forcibly placed on the stand, the dog began to breathe heavily, to tremble and to whine; he stood with sagging limbs, tail between his legs and head drooping; he did not react to any conditioned signals or manifested phenomena of the ultra-paradoxical phase; he turned away from food. Forcible feeding led to a drastic decline of the alimentary unconditioned reflex. It can be assumed that in this case the inhibitory process irradiated extensively and deeply, embracing not only the artificial and natural conditioned connections, but also the unconditioned reflexes (the subcortical regions). However, while in the stand, the dog did not sleep and did not even drowse. This state lasted for more than two months and fully disappeared after rest, relaxation of the experimental conditions and administration of bromides.

The question now arises, what are the common and differing features of the extensive irradiation of inhibition, which, upon passing through a number of transitional states, leads to drowsiness and sleep, and the irradiation just mentioned by us. The present state of our

knowledge is still insufficient to provide an exhaustive answer to this question. But it is a striking fact that in the latter case it is mainly the effector parts of the brain that reveal a heightened susceptibility to inhibition, as if retaining the inhibitory process within their confines; at the same time there is clearly observed an emergence, disinhibition of peculiar passive-defensive postures and reactions, however, qualitatively differing from those described by us in previous cases, as well as an absence of phenomena of muscular numbness (it is possible that the phenomena of positive induction develop here not at the same level as in cases of general motor excitation which has the character of passive-defensive reactions; at any rate, the phenomena of inhibitory irradiation in our case are more pronounced and extensive). The whole picture is, as it were, of a depressive character.

The following fact comes clearly to the fore: the disturbances of the general behaviour of animals (on the experimental stand and outside it) in the course of pathological states evoked by nervous breakdowns, may manifest themselves in two different ways: a) in states of limpness and drowsiness during which there arise transitional states characterized by a different extensity of diffused irradiated inhibition and by catatonia-like phenomena; b) in the derangement of proper correlations between the excitatory and inhibitory processes, more often accompanied by phasic states (equalization, paradoxical, ultra-paradoxical, inhibitory and other phases), and by pronounced defensive reactions (passive or active—under breakdowns of an excitatory character).

In both groups there are cases which sometimes produce a particularly strong impression of rough models of psychogenic diseases.

A separate place is occupied by circular, cyclical pathological states caused by functional influences; but it would be hardly correct to call them only circular neu-

roses—they resemble circular neuropsychical diseases in man (cyclothymia and cyclophrenia).

However, it should not be forgotten that all these comparisons are of a highly relative character and refer only to the most general and elementary properties of nervous activity.

Still, there is no doubt that the so-called experimental neuroses are simplified designs of diseases caused by the difficult tasks demanded from the nervous system by the external environment, under the influence of conflicting situations leading to overstrain and breakdown of the higher nervous processes and to pathological phenomena not always confined to the bounds of neuroses or neurotic states.

Pavlov said: "The morbid states of the nervous system, which we have produced, correspond to a considerable extent to so-called psychogenic illness in human beings."*

6

VEGETATIVE DISTURBANCES CONNECTED WITH EXPERIMENTAL NEUROSES

We have pointed out more than once, although in passing, that in the course of experimental neuroses many experimenters often observed, together with general changes in the behaviour of the animals, distinct disturbances of vegetative functions in the shape of dyspnoea and abundant salivation, or, on the contrary, of a considerable decline of unconditioned salivary secretion, etc.

However, as proved mainly by the observations of M. K. Petrova, besides such relatively slight functional changes there often take place more profound vegetative disturbances, mostly of a neuro-dystrophic charac-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 688.

ter, in the shape of eczematous phenomena, ulcerous processes, etc. Unfortunately, the general picture and the dynamics of vegetative changes resulting from and connected with nervous breakdowns, and accompanying the subsequent pathological states of the higher nervous activity in animals, remain up to now relatively little investigated.

All the greater, therefore, is the significance of the experimental investigations carried out in this field by M. K. Petrova, K. M. Bykov, M. A. Ussievich and their collaborators.

K. M. Bykov* describes several cases of experimental neuroses observed in dogs in his laboratory and connected with disturbances in the functions of the internal organs. The phenomena of collision and neurosis were first observed when, during the rehabilitation of an extinguished interoceptive conditioned reflex, a clash between the excitatory and inhibitory processes occurred in the cortex. A similar disturbance was observed when an attempt was made to apply exteroceptive conditioned stimuli on the background of an extinguished interoceptive reflex (Pishin). After extinction the interoceptive conditioned reflex proved to be inconsistent, producing now a positive, now an inhibitory reaction. The moment the previously elaborated exteroceptive reflexes were applied it turned out that they were either in a state of complete inhibition, or revealed intermediate, transitional, phasic states. Thus, the extinction of the interoceptive conditioned reflex, which was a difficult process, originated phenomena of experimental neurosis in the exteroceptive conditioned reflexes.

A five-month interval in the experiments with the dog resulted in complete restoration of normal correla-

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* K. M. Bykov, *The Cerebral Cortex and the Internal Organs*, 1942, pp. 366-67.

tions between the excitatory and inhibitory processes, and simultaneously in complete restoration of the previously disturbed interoceptive and exteroceptive conditioned reflexes.

Particularly pronounced and durable disturbances of a neurotic character were obtained in K. M. Bykov's laboratory in the following case. Conditioned reflexes were elaborated in each of five experimental dogs to different unconditioned stimuli—electric cutaneous, defensive and alimentary (I. A. Vetiukov). During the experiments not only the defensive movements of the animal's limb and its salivary secretion were registered, but also the respiratory movements of the thorax. This made it possible to obtain data characterizing the state of the motor activity, as well as of the digestive and respiratory systems.

At first the motor defensive conditioned reaction grew steadily, and the secretory, alimentary reaction, on the contrary, diminished, until the alimentary conditioned stimulus was transformed into a conditioned stimulus of defensive reaction.*

Along with these changes there was observed an ever growing general motor excitation accompanied by whining and barking. Later on, the conditioned stimulus of defensive reaction began to slow down the respiratory rhythm and to evoke salivary secretion. At the same time the alimentary conditioned stimulus again produced a secretory effect.

Continuing to apply conditioned stimuli, but not reinforcing them by unconditioned stimuli, the experimenter obtained acute disturbances of the nervous activity having the character of experimental neurosis. The application of conditioned stimuli invariably evoked bark-

* Similar experiments were performed at one time in the Pavlov laboratory by his co-worker G. P. Konradi.

ing, howling, an extremely quickened respiration, and, what is of particular interest, distinct disturbances of the gastro-intestinal system. Under each application of the alimentary conditioned stimulus (sounds of the metronome) the dogs not only rejected food, but grasped the air in time with the beats of the metronome, made swallowing movements accompanied by spasms of the abdominal muscles, and, finally, vomited. The action of a conditioned stimulus of defensive reaction produced also derangements of muscular co-ordination: the dogs threw up their heads, simultaneously revealing an increased extension in their fore limbs and a loss of tone in the hind limbs.

K. M. Bykov believes that the above-described neurotic state reflects disturbances not only of the cortical but also subcortical activity. Sexual excitation in male dogs at the sight of female dogs led to the aggravation of the neurotic state and even resulted in the paresis of the hind limbs. Rest, following discontinuance of the experimental work, returned all animals to normal.

One cannot but agree with the following statement of K. M. Bykov: "It is surprising how violently the normal activity of the central nervous system is deranged by the harmless sounds of a metronome, or of a bell—so great is the significance of the cortical cells for determination of the fundamental vital functions in everyday life."*

Of great interest are the experimental data obtained already in Pavlov's lifetime and in his laboratory by M. A. Ussievich (subsequently M. A. Ussievich and his collaborators continued the elaboration of these data independently).

* K. M. Bykov, *The Cerebral Cortex and the Internal Organs,* 1942, p. 366-67.

M. A. Ussievich investigated the influence of various changes in the cortical dynamics (the development of new positive and inhibitory connections, the processes of irradiation and concentration, the phenomena of induction, etc.) upon the functioning of the internal organs.

At the same time he devoted much attention to the influences which are exerted on the activity of these organs by collisions between the excitatory and inhibitory processes, by the reshaping of the dynamic stereotypes, by nervous breakdowns and experimental neuroses.

Here are some of M. A. Ussievich's experiments: In a dog, whose ureters were brought out by the usual fistula method (slightly modified by L. A. Orbeli) in order to investigate the diuresis, a dynamic stereotype was elaborated by the salivary method; after this a new conditioned stimulus was introduced which resulted in considerable derangement of the stereotype and in a lasting inhibitory after-effect. Under these conditions the diuresis proved to have greatly increased. Subsequently this experiment was repeated and produced the same results, which M. A. Ussievich ascribes to the fact that the inhibition of the cortical activity tends to liberate, to disinhibit the work of the internal organs. However, in another dog with a strong inhibition of the cortex caused by heat and accompanied by phasic phenomena, on the contrary, there was observed a considerable decrease in diuresis, which M. A. Ussievich is inclined to attribute to irradiation of inhibition. Recovery was attained by administering bromides.

In one of the dogs with an isolated Pavlov stomach pouch a collision was produced by means of a quick transition from an inhibitory (differential) stimulus to a positive conditioned stimulus. The collision resulted in a persistent neurotic state of an inhibitory character with marked phenomena of drowsiness which lasted for

many weeks. Throughout this period gastric secretion increased considerably.

This time, too, systematic administration of bromides gave good results; it eliminated both the disturbances of cortical dynamics and the derangement of gastric secretion. M. A. Ussievich believes that in this case the experimental neurosis depressed the cerebral cortex, disinhibited the subcortical regions and thus caused an increase in the secretory activity of the gastric glands.

Repeated collisions effected in a dog, with the pancreatic duct brought out to the external surface, caused only insignificant disturbances of the higher nervous activity, not assuming the extent of experimental neurosis; certain fluctuations of pancreatic secretion were observed, but these were not sufficiently distinct.

In another dog the bilious duct was brought out to the external surface in conformity with Pavlov's perfected method. Then a collision was produced by direct transition from an inhibitory to a positive stimulus; as a result of this collision, pronounced disturbances of the cortical activity with a predominance of the inhibitory process and with phenomena of drowsiness were observed in the dog for a period of three days. Under these conditions considerable changes took place in the course of bile secretion, and, in particular, there was a marked tendency towards its intensification. In three days the after-effects of the collision were obliterated. Subsequently an attempt was made to reshape the dynamic stereotype in the same dog; this proved to be a very difficult and very slow process accompanied by distinct, although not acute, disturbances of the usual course of bile secretion.

Thus, the experiments of M. A. Ussievich showed that collisions between the excitatory and inhibitory processes, the long struggle of these processes in the

course of reshaping the dynamic stereotypes, the breakdowns in nervous activity and experimental neuroses caused by them, are followed by disturbances in the activity of internal organs, most strikingly manifested in the digestive organs. With the elimination of the neurosis these disturbances disappeared.

Also of great importance for the clinic are the experimental data and observations of M. K. Petrova and her collaborators. We shall speak of them only in brief since they were expounded and summed up by M. K. Petrova in a special monograph entitled "The Role of the Functionally Weakened Cortex of the Brain in the Development of Various Pathological Processes in the Organism" (1946).

The experiments and observations made by M. K. Petrova in the course of many years on normal and castrated dogs (the latter will be discussed by us subsequently) provided valuable data proving that animals which repeatedly underwent severe collisions, nervous breakdowns and experimental neuroses, in contrast to those not subjected to them while under observation during the same period, usually exhibited pronounced chronic processes of skin dystrophy in the shape of various eczemas (both exsudative and scaly), loss of hair, furunculosis and various ulcerous processes (sometimes otitis and arthritis were also observed).

With recovery from the experimental neuroses and restoration of the normal higher nervous activity, all these disturbances, as a rule, vanished and reappeared with each new breakdown and with the ensuing prolonged pathological state of the cortex.

"We know," M. K. Petrova wrote, "that on the skin of all of our experimental dogs, and they are far from being irreproachable in the matter of cleanliness, there is a multitude of various micro-organisms, and that all dogs are kept in the same conditions and get the same

food; however, as already mentioned, no internal or skin diseases were observed in the dogs which almost all the time had been in conditions favouring their nervous systems and in a state of full equilibrium. But in the dogs which were affected by such diseases, so long as they remained in a state of full nervous equilibrium, with the functional properties of their cortices invariable and the physico-chemical processes normal, the micro-organisms were inactive, not pathogenic and could not cause any skin disease. But the moment the cortex became exhausted under the action of our morbific procedures, aimed at its weakening, its functional properties were disturbed, and the central station could no longer properly perform its regulative functions, the micro-organisms populating the skin became active, pathogenic, and provoked the above described skin and other diseases. The weakened cortex was no longer able to prevent the development of pathological processes."*

The development of papillomas was observed in some dogs which had been frequently and for considerable periods of time subjected to neuroses; in most of these, in contrast to the experimental animals not subjected to collisions and breakdowns, dissection revealed neoplasms in the internal organs, mainly of a malignant character (cancer of the lungs, of the urinary bladder, and of the thyroid gland with numerous metastases, hypernephroma, sarcoma, etc.), and, in rare cases, neoplasms of a benign character (fibroma, adenoma).

The fact that all these neoplasms were found only in the experimental dogs which for years had been subjected to repeated and severe functional nervous traumas, naturally led to the assumption that this coincidence was not accidental, that the first impetus to the de-

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* M. K. Petrova, *The Role of the Functionally Weakened Cortex of the Brain in the Development of Various Pathological Processes*, State Medical Publishing House, 1946, pp. 41-42.

velopment of these diseases was produced by disturbances of the nervous, and above all, of the cortical activity.

Consequently, M. K. Petrova decided to subject two groups of dogs (approximately of the same age) to the regular and protracted action of cancerogenic substances, and first of all, of gaseous coal-tar. Whereas all the dogs of one group (four dogs) were subjected to repeated collisions and breakdowns, and thus brought into a lasting and severe neurotic state, all the dogs of the second group (a control group consisting of five dogs) were left fully intact in this respect, i.e., were completely released from experimental neuroses. As to the application of the coal-tar, both groups of dogs were placed in equal conditions: in order to obtain epidermal tar cancer the coal-tar was always applied to one and the same area of the skin—between the shoulder blades—measuring 10 square cms.; this was done once every two days for a period of two and a half years, and then, after a six months' interval, for another year. After 300-330 applications of the tar, collisions and breakdowns were evoked in each dog of the experimental group (as already mentioned this was not extended to the dogs of the control group).

This experimental work, started by M. K. Petrova and her collaborator, A. K. Voskresenskaya, in the first half of 1938, was interrupted by the Great Patriotic War and could not be carried out on the scale originally conceived. Nevertheless, the results achieved are of great interest and value. It turned out that the control dogs, after the application of gaseous coal-tar for a period of three and a half years, exhibited only phenomena of dermatitis, thickening and chapping of the skin; the small papillomas which developed on the skin, disappeared upon discontinuance of the application and did not reappear.

A different picture was observed in the dogs subjected to experimental neuroses: after two years of regular application of coal-tar there began an abundant and progressing development of papillomas which spread to the skin areas not subjected to the action of tar.

It should be pointed out that the application of the tar evoked violent pain reaction in all the dogs, both of the experimental and control group. But, other conditions being equal, the experimental neurotization of the animals played, of course, the decisive role.

These experiments quite clearly revealed the significance of the functional pathological states of the higher parts of the central nervous system for the genesis and development of tumours.

Since mice are the most convenient and suitable objects for obtaining experimental cancer (they produce a reliable and quick effect), M. K. Petrova decided to experiment with them in the same way as she did with the dogs. Unfortunately, this work, started in 1940 (and carried out by E. F. Melikhova), was also interrupted by the war; nevertheless, it produced certain results which have been described by M. K. Petrova.

Two groups of mice (an experimental group and a control group) were regularly subjected to the application of dibenzpyrene, a cancerogenic substance more powerful than coal-tar; at the same time the first group was subjected to nervous traumatization by means of an electric current in specially equipped electrode cages (designed by Dunayevsky). In two or three months phenomena of dermatitis were observed much more frequently in the first group than in the second, and three or four months later the same could be said with regard to papillomas. Thus, the first preliminary results of these experiments fully confirmed the data obtained with the dogs.

In elucidating the pathogenic mechanisms of the influence of experimental neuroses on the development of tumours, M. K. Petrova prefers the neuro-dystrophic point of view.

The experimental investigations of M. K. Petrova, K. M. Bykov, M. A. Ussievich and their collaborators showed convincingly that functional pathological states of the higher parts of the brain, caused in animals by collisions, overstrain of nervous processes and nervous breakdowns, are manifest not only in derangement of their external behaviour, but also in various profound changes in the internal medium of the organism, in the functioning of the internal organs, in the vegetative functions, thus embracing the whole organism.

These investigations, begun in Pavlov's lifetime, assumed a particularly wide scope after his death.

A number of new and important problems have arisen in this connection. They include: the dynamics of the development of vegetative disturbances in the course of experimental neuroses; their dependence on various forms of overstrain of the cortical processes and on various forms of experimentally induced disturbances of the higher nervous activity; the connection between these vegetative disturbances and the specific properties of the type of nervous system, etc.

GENERAL AND LOCAL DISTURBANCES RESULTING FROM EXPERIMENTALLY INDUCED FUNCTIONAL DISORDERS OF THE BRAIN

"By means of our noxious measures with which the whole cerebral cortex is made pathological," Pavlov said, "it is also possible to cause an entirely isolated area of the cortex to become ill; this is an extremely

important and very impressive fact."* Under the influence of various noxious causes of a functional character "isolated pathological points or areas" may develop in certain parts of the cerebral cortex.

However, it would be absolutely wrong to interpret literally this formulation which is sometimes used in Pavlov's works—when speaking about "isolated points or areas," he always endeavoured to simplify and deliberately to schematize matters in order to facilitate as much as possible the understanding of highly complex phenomena actually taking place in the cortical dynamics.

Hence, here we meet not with a "rough and mechanical simplification of facts," but with the wise, pedagogical popular scientific and literary method so characteristic of the works of Sechenov and Pavlov in general.

Under "isolated pathological points" in the cortex Pavlov actually implied something similar and related to the phenomenon of the dominant which had been investigated and described by another remarkable Russian physiologist A. A. Ukhtomsky, the main difference being that here it is a question of the pathological dominant. The concept of "isolated pathological points" stands close also to the idea of functional foci of pathological excitation and inhibition, or, to be more exact, of functional centres where the correlations between the excitatory and inhibitory processes are pathologically deranged, and which, as we shall see later, become in one form or another, and for a longer or shorter period of time, the source of pathological dynamic changes in the whole cortex; all this makes their isolation highly relative. Finally, as stated by Pavlov himself, by "isolated pathological points or areas" in the cortex he by no means implied a particular group of nerve cells localized in a certain point. He held that "it is a question of

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 692.

a dynamic structural complex, the elements of which, the corresponding cells, take part also in other dynamic complexes...."* In other words, it is a question of pathological dynamic structures, uniting and connecting different cortical neurones, different nervous paths and, perhaps, different areas of the cerebral cortex as well.

"In the processes which connect and systematize the dynamic complexes," Pavlov wrote, "our noxious methods create difficulties, the results of which are the basis of the disturbances and destructions in those complexes."** From this it clearly follows that, in Pavlov's understanding, the question is much more complicated than it may seem at first sight after superficial acquaintance with his concept of "isolated pathological points or areas."

The first experimental facts underlying this concept were obtained way back in the twenties; but the experimental work done in the Pavlov laboratories in this field acquired a particularly large scale during the last years of his life and was closely connected with his research into clinical patho-physiology.

In 1925 V. V. Rickman, experimenting with one of his dogs of the inhibitory type, began to transform an old and firmly established metronomic differentiation (applied 266 times) into a positive conditioned reflex. It turned out, however, that the transformation of the inhibitory stimulus into a positive was a matter of great difficulty. The conversion of the inhibitory connection in the cortex into a positive was very slow and incomplete; it was absolutely impossible to obtain a stable effect and, at the same time, symptoms of a local pathological disturbance became more and more pronounced. As a rule, each trial of the reshaped differential stimulus

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 693.
** *Ibid.*

(sixty beats of the metronome per minute) either at once or a little later began to evoke, in response to the application of all other conditioned stimuli (especially strong ones) acting on various analysers, phasic states in the shape of equalization, narcotic, paradoxical and inhibitory phases. On one of the experimental days when the differential stimulus (sixty beats of the metronome per minute) was not applied, the animal's cortex functioned quite normally, but as soon as the stimulus was introduced, the development of phasic states throughout the whole cortex (lasting from several hours to several days) could be observed again. It is interesting that in a very short while the positive stimulus—120 beats of the metronome—acquired the same pathogenic character as the differential stimulus—sixty beats of the metronome; at the same time all other conditioned stimuli (without the application of metronomes) did not show any deviations from normal. But the moment the pathological point was touched (by application of one of the metronomic rates), all conditioned stimuli ceased producing their usual effect and the cortex went over to a pathological state. Each application of the metronome invariably disrupted the normal activity of the cortex. Pavlov stated:

"Since other auditory stimuli by themselves continue to act quite normally, it must be assumed that in this case we meet with a partial, strictly localized disturbance of the acoustic analyser, so to speak, with a chronic functional lesion of it, the adequate stimulation of which affects the entire cortex, and evokes in it, finally, a protracted pathological state."*

While in this case derangement of a definite complex of conditioned connections, of a definite dynamic structure, is markedly manifest in the animal's cortex,

* I. P. Pavlov, *Lectures*, p. 270.

still there is no ground to speak of its *complete* isolation; the isolation is of a highly relative character.

In the various pictures of experimental neuroses, which we have seen up to now, it is the general disturbances of cortical dynamics that are usually the first to be noted. In this case a local disturbance comes to the fore; however, the local disturbance has a distinct tendency, under certain conditions, to develop into general disturbances, as if of a secondary character. Concerning the nervous mechanisms responsible for these pathological phenomena, Pavlov said: "The final disturbance of the activity of the entire cortex, which has just been described, can be regarded as being produced in either of two ways. First, it is possible that the stimulus, which evokes excitation in the disturbed area, intensifies the inhibitory process, and makes it stationary for a certain period of time; simultaneously, the irradiating inhibition involves all other cortical cells. Second, it is possible that the stimulus acts on this area as an injurious agent, and then, exactly as in the case of any other area of the body subjected to destruction, this area, due to the mechanism of external inhibition, involves all other parts of the hemispheres in a state of inhibition. Obviously, the development of a localized disturbance is the result of a collision between excitation and inhibition."*

When Pavlov made this statement the concept of overstrain of the mobility of nervous processes, introduced by him later, did not yet exist; however, this particular case falls precisely within this very category.

Subsequently, local disturbances similar to those first obtained by V. V. Rickman were repeatedly observed (mainly in 1932-1933) in a number of dogs and were described by M. K. Petrova.

* I. P. Pavlov, *Lectures*, pp. 270-71.

These local disturbances, usually caused by the simultaneous transformation of both the positive stimulus and the respective differential (inhibitory) stimulus into stimuli of opposite sign, i.e., by the reshaping of the simplest dynamic stereotype and at the same time by overstraining the mobility of nervous processes, developed into general disturbances of cortical dynamics under certain conditions (when one of the reshaped stimuli was tested).

Still earlier (in 1927) M. K. Petrova met with an analogical case when repeated collisions were developed in a dog by a quick transition from an inhibitory to a positive stimulus, both stimuli being tactile but differing in frequency of rhythm. After the breakdown, each application of the previously positive and now broken-down cutaneous stimulation (pricking apparatus) which became inhibitory was immediately, or in one or two days, followed by the development of phasic phenomena in the cortex (mostly the paradoxical phase). On experimental days when the stimuli related to the pathological focus formed in the cutaneous analyser were not applied, the dogs, as a rule, behaved quite normally.

A similar case, this time connected with the acoustic analyser, was observed in 1938 by O. P. Yaroslavtseva in the course of repeated collisions between two tone stimuli (a quick transition from an inhibitory to a positive stimulus).

Of great interest is the following case observed by M. K. Petrova. In the cutaneous analyser, when a differentiation according to place was elaborated (stimulation of one point of the skin was reinforced, while stimulation of the other was not), a breakdown of the nervous activity took place; however, it manifested itself only when the tactile differential (inhibitory) stimulus was applied at least once. But the moment it was administered the animal fell into a state of violent rage, reacting

exactly as it had done to a very strong, painful stimulus. At the same time all conditioned reflexes passed over into phasic states.

Of no less interest is another case observed by M. K. Petrova. This time the local disturbance consisted in that when the positive and the differential (inhibitory) rates of the metronome were applied, both stimuli invariably exhibited phenomena of the ultra-paradoxical phase, while all other conditioned stimuli did not reveal any phasic states at all. However, later it was observed that under the action of metronomes, phenomena of explosiveness (excitatory weakness) emerged in the cortex; when the metronomes were excluded from the experiment all the conditioned reflexes weakened and a state of acute drowsiness developed.

Quite a different form of local disturbance was described by V. V. Rickman (1932). In one of his dogs a defensive conditioned reflex to an auditory stimulus (tone "D") had been elaborated through a strong unconditioned stimulation of one of its paws by an electric current.

With the second application of these stimuli there developed a strongly pronounced defensive conditioned reaction which grew into general motor excitation and proved to be very stable; thereafter its conditioned stimulus was not applied for a considerable period (about eighteen months), and all manifestations of the defensive reaction connected with it fully disappeared.

However, when, as a result of the elaboration of alimentary conditioned reflexes to strong stimuli, phasic states, and particularly the paradoxical phase, began to develop in the dog, on the background of these intermediate states between wakefulness and sleep, a distinct defensive reaction suddenly manifested itself in the intervals between the application of alimentary conditioned stimuli; this occurred despite the fact that the condi-

tioned stimulus of this reaction, as already mentioned, had not been applied for a long time. Thus, the general inhibitory state of the cortex evoked (possibly through positive induction) the disinhibition, the revival and activization of the traces of the defensive conditioned connection earlier elaborated and impressed in the cortex.

Intensifying the excitability of the cortex with the help of caffeine, Rickman eliminated, along with the phasic states, the defensive reaction. He regarded the peculiar local disturbance observed by him as an analogue, as a simplified model of the so-called traumatic neurosis, a model precisely of those of its forms when the intermediate state between wakefulness and sleep evoked in the patients phenomena of "fighting automatism," reproducing battle scenes and episodes experienced by them during the war. However, even in this case, described by Rickman, the local disturbance was closely connected with the general derangement of cortical activity, on the background of which it had appeared. A number of authors (M. K. Petrova, N. A. Podkopayev, V. V. Yakovleva and others) described more or less analogical cases of various defensive reactions (persistent stereotype attempts to tear off the salivary bulb by the paw, a stereotype twitching of the paw, scratching, frequently repeated shaking of the whole body, etc.); they appeared only under diffused inhibition in the cortex, but rather bore the character of disinhibited subcortical unconditioned reactions, and sometimes of spinal reflexes. A common feature of all these cases is the emergence of motor unconditioned, or conditioned, reactions previously elaborated but not applied for a long period; these reactions repeatedly reappear in a stereotype form, but always in the presence of an inhibitory process irradiated over the cortex, and of intermediate states between sleep and wakefulness when the cortex, in Pavlov's words, is enveloped in a "haze of inhibition."

Local disturbances entering the last group are expressed in pathological changes of the mobility of the excitatory or inhibitory processes and are caused by their overstrain.

In the course of reshaping two stimuli (a positive stimulus and an inhibitory, differential one) when reinforcement of the positive stimulus was discontinued, and the inhibitory, on the contrary, was regularly reinforced, M. K. Petrova obtained in some dogs a peculiar form of local disturbance by applying mainly acoustic stimuli, and in separate cases—tactile stimuli.

Despite frequently repeated application of the positive stimulus without reinforcement, the extinction of the conditioned reflex, which was naturally expected, either could not be obtained at all, or it was elaborated with great difficulty, and even then in an utterly unstable and incomplete form. At the same time, under the action of other stimuli, there were observed now and then intermediate states between wakefulness and sleep and sometimes the development of even deep sleep. Thus, the difficult experimental task evoked a local disturbance expressed in the fact that one of the conditioned stimuli became pathologically inert; this pathological inertness of the excitatory process manifested itself mainly in the impossibility of extinguishing the conditioned reflex connected with this stimulus. However, in such cases, too, as we see, the local disturbance was only relatively isolated and, from time to time, produced a more or less pronounced effect throughout the cerebral cortex.

In some dogs, as a result of frequent collisions, the positive stimulus, while being transformed into an inhibitory one, began to display phenomena of pathological inertness of the inhibitory process; this was expressed in the fact that despite regular and protracted reinforcement of this positive stimulus (in one case during a period of three years), all attempts to liberate it from inhibition,

to disinhibit it and to return to a positive effect, completely failed, or yielded favourable results only after special treatment (M. K. Petrova, V. V. Yakovleva and others). In separate cases, under the influence of a collision, the conditioned stimulus began to produce a very rapid and considerable effect, although susceptible to quick exhaustion, i.e., its action assumed, as it were, an explosive character. Pavlov was inclined to regard such cases as a manifestation of pathological lability of the excitatory process, which is as yet but little investigated.

We have dealt up to now with phenomena of pathological inertness mainly in the acoustic and cutaneous analysers. But, as we shall see, they can also develop in the motor analyser.

In one of the experimental dogs of I. I. Filaretov (1930-1931) there was applied among other conditioned stimuli a very weak noise which was barely audible and made the animal strain to the utmost in listening (acoustic orienting reflex). This was accompanied by a peculiar motor reaction, which consisted in the following movements: the dog approached the edge of the table (on which the stand was mounted) and since the source of the weak noise (a megaphone) was under the table, tried hard to catch sight of it and approach it in every possible way, falling on its forelegs, pawing with them in turn over the edge of the table and bending its head as low as it could. At first this reaction was the dog's response to the weak acoustic conditioned stimulus, but some time later it was extended to all other conditioned stimuli, although none of them came from under the table. Consequently, the reaction assumed an obviously inadequate character, not corresponding to reality, i.e., a pathological character. This reaction was fully retained even when in the course of further experiments with other conditioned stimuli the weak noise was no longer applied as a conditioned stimulus, subsequently appearing not only

in response to various conditioned signals but also during intervals between them.

In Pavlov's opinion, this pathological phenomenon is explained by the following: the extreme weakness of the barely audible noise evoked in the animal excessive strain of the orienting motor apparatus both of the general locomotor and the special orienting, accommodative and adjusting auditory apparatus, the receptor of the given stimulation. After numerous repetitions this led to overstrain of the excitatory process and to the emergence of a highly stable, persistent and chronic local disturbance in the form of pathological inertness of excitation.

It should be pointed out that in this case, too, the local disturbance was not fully isolated, but secondarily spread to a number of other stimuli (which leads to the supposition that a pathological dominant was developed in the cortex). Phenomena of pathological inertness of the excitatory process, which manifested themselves in inadequate movements—twitching of the hind leg, insistent licking of the electric bulb (source of the conditioned stimulation), and various other movements—were also noted by other experimenters in the Pavlov laboratories (S. V. Klestchov, V. P. Golovina, V. V. Yakovleva and others.*)

Study of the origin of such local disturbances usually revealed their connection with previous overstrain of the excitatory process.

These disturbances emerged not on the background of inhibition, of phasic phenomena, but rather following

* Observing local disturbances caused by pathological inertness, physiologists are apt to term them "obsessive" phenomena, which is absolutely inadequate. The psycho-pathological concept of "obsession" in no way means that pathological phenomena (for example, obsessive movements) are obtrusive upon those who surround the patient, but exclusively upon the patient himself. Consequently, this term actually cannot be applied to animals, at least in the generally accepted sense.

any more or less noticeable increase in cortical excitability (various stimuli pouring into the cortex to a certain degree became subdominant in relation to such a pathological dominant).

The division of the above-described local disturbances into three groups (namely, those connected with a pathological functional focus; those positively induced by diffused cortical inhibition, and, finally, those accounted for by local pathological derangement of the mobility of cortical processes) is, of course, of a very relative character; it makes no claim whatever to completeness and is necessitated by the desire to provide at least a temporary systematization of these phenomena in order to facilitate exposition of the subject; it is possible that with further study more comprehensive and profound forms of systematization will be required.

Comparing the general disturbances of the higher nervous activity in animals which we observed during investigation of the various forms of experimental neuroses, with the above described local disturbances, we must stress some of their common and differing features.

In both cases we meet with pathological disturbances resulting from overstrain of the nervous processes. But in the first case immediately after the collision, or some time later, the pathological disturbances manifest themselves simultaneously in the entire cortex, or at least in the activity of a number of its analysers, as if overshadowing and disguising the initial source of these functional changes. In the second case the pathological disturbance, also more often caused by collision, is localized in a certain analyser, in one or another complex of connections, in one or another dynamic structure. But under certain conditions it always tends, more or less markedly, to grow into general disturbances of the cortical dynamics or to emerge on their background.

Thus, in discriminating between general and local

pathological states of the higher nervous activity, evoked by harmful functional influences in the shape of difficult experimental tasks or severe situations in the surrounding world (floods, for example), one should not forget that such discrimination is highly relative, and that these states undoubtedly have common features.

When studying the different forms of experimentally induced disturbances of the higher nervous activity, Pavlov always strove to investigate the means of treating them and eliminating them; but these experimental therapeutic investigations will be dealt with later on.

In 1931 Pavlov wrote: "To draw in earnest analogies between the neurotic states of our dogs and various human neuroses is a task hardly feasible for us, physiologists, who have no thorough knowledge of human neuropathology. But I am convinced that the solution, or a substantial contribution to the solution, of many important problems relating to the aetiology, natural systematization, mechanism, and finally, treatment of human neuroses is in the hands of those who experiment with animals."*

If we view in retrospect and trace the history of the theory of experimental neuroses in Pavlov's lifetime, we shall discern in it several successive stages which overlap and gradually supersede one another.

In the first stage (covering approximately the period 1922-1925) investigation was focussed on the basic forms of nervous breakdowns both of an excitatory and inhibitory character; this investigation established a certain connection between them and the types of the higher nervous activity; it revealed the dependence of these breakdowns not only on difficult experimental tasks, but also on severe situations in the external environment (a flood, for example); it described for the first time phasic states

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 575.

in the cerebral cortex and their appearance as a result of collisions; and finally, substantiated the concept of experimental neurosis.

The second stage, which greatly enriched the experimental data and made possible their considerable differentiation by generalizing various "difficult tasks," defined the concept of overstrain of the excitatory and inhibitory processes, as well as of their mobility; it showed that the dependence of the nervous breakdown and of its form on the type of nervous system is of a highly relative character and calls for many substantial corrections, that experimental neuroses may be obtained not only in animals belonging to unequilibrated types, but also to equilibrated, strong types; it described the circular, cyclic disturbances of the higher nervous activity and considerably differentiated its phasic states; it initiated the study of vegetative disturbances connected with collisions and breakdowns; the bounds of experimental neurosis became too narrow to embrace the rich variety of pathological states of the higher nervous activity caused by noxious functional influences.

Finally, in the last stage, research was concentrated on the pathological changes of the mobility of cortical processes and on "isolated pathological points," or to be more precise, on pathologically changed dynamic structural complexes, on local disturbances and their connection with general disturbances of the cortical dynamics.

As we know, after Pavlov's death, further experimental work in this field was directed mainly to the investigation of the influences exerted by pathological states of the cortex on the internal medium of the organism, on changes in the vegetative functions and on somatic diseases (M. K. Petrova, M. A. Ussievich and others).

In one of his last articles (1935) Pavlov stated: "Experimental study of pathological changes in the basic

processes of the nervous activity of animals makes possible a physiological understanding of the mechanism of the mass of neurotic and psychotic symptoms, both taken separately or as components of definite pathological forms."*

8

PATHOLOGICAL CHANGES OF THE HIGHER NERVOUS ACTIVITY CONNECTED WITH EXPERIMENTALLY INDUCED DISTURBANCES OF THE ENDOCRINE AND VEGETATIVE FUNCTIONS

The Pavlov school studied the pathological states of the higher nervous activity resulting from noxious functional influences not only in cases where these states were caused by difficult experimental tasks and severe external conditions, but also where they were obtained as a result of artificially induced disturbances in the internal medium of the organism, in the functioning of the internal organs and, above all, in the activity of the endocrine and vegetative systems.

However, before describing pathological changes in the nervous system due to endocrine disturbances experimentally obtained in animals, it should be stressed that, according to the Pavlov school, distinct, but fleeting and quite reversible changes of the higher nervous activity appear also under endocrine-vegetative readjustments of a purely physiological, not pathological, origin. For example, during the period of heat (K. N. Krzhishkovsky, E. M. Kreps, M. A. Ussievich and others), or in the period of pregnancy and lactation (D. S. Fursikov, O. S. Rosenthal, I. R. Prorokov and others) clearly marked functional changes are observed in the higher nervous activity

I. P. Pavlov, *Twenty Years of Objective Study*, p. 734.

of dogs: decline and instability, first of artificial conditioned reflexes and then also of natural ones; disinhibition of differentiations; phenomena of drowsiness; undulatory fluctuation of cortical excitability with a predominance of phenomena of diffused inhibition, etc. All these changes reflect first of all the processes of external inhibition (negative induction) emanating from the physiological dominant which arises in the system of nervous centres responsible for the instinct (complex unconditioned reflex) of reproduction.

It is noteworthy that, in the course of recovery of the higher nervous activity, the natural conditioned reflexes, according to the observations of I. R. Prorokov, are the first to return to normal.

This shows that the cerebral cortex is highly reactive to vegetative-endocrine changes.

Of all the pathological states developing in the higher parts of the central nervous system under the action of artificially obtained endocrine disturbances, those connected with castration have been most elaborately and thoroughly studied. Fundamental investigations in this field were carried out by M. K. Petrova and A. M. Pavlova.

A number of dogs castrated at different ages and belonging to different types of nervous system were subjected to experimental investigation in the course of which the dynamics of development and succession of disturbances in the higher nervous activity caused by castration were thoroughly registered. Peculiarities observed in the castrated dogs under collisions, breakdowns and in the course of experimental neuroses were also studied in detail. Many interesting and valuable facts were noted as a result of the experimenters' attempts to check or to eliminate the defects of the nervous activity caused by castration, and to cure some experimental neuroses of a particularly grave character.

It is obvious that castration greatly disrupts normal relations in the animal's nervous system; it changes for a more or less considerable length of time and to a certain degree, the force, equilibrium and mobility both of the excitatory and inhibitory processes. One of the most striking disturbances appearing very soon after castration is a very marked diminution of the processes of internal, active, inhibition. However, the nature of the changes occurring in the higher nervous activity after castration, as well as the dynamics of the progressive and reverse development of these changes, greatly depend on the specific properties of the type of nervous system.

In representatives of the strong type these disturbances manifest themselves in a particularly marked form during the first months following castration, after which they gradually die down. In representatives of the weak type they persist for many months, and, in some cases, even for several years.

But there is one distinction between the representatives of the strong and weak types of nervous system, which at first sight seems surprising and incomprehensible. In the representatives of the strong type we normally meet with a well-elaborated system of conditioned connections, which, from day to day, maintains a strictly regular, stereotypically exact and uniform picture. After castration the picture changes almost immediately and abruptly: the experiments no longer resemble one another; there is no trace of order and exactness in the experimental work which fluctuates and changes day after day, becoming distorted, losing regularity and assuming a chaotic character.

Quite different is the picture in representatives of the weak type. Here, for some time after castration, the behaviour does not show any change for the worse during experimental work; on the contrary, the dogs behave

better, in a more regular manner and more orderly than before the operation.

This, however, is observed only during one or two months, after which these dogs, too, display a picture of disturbances of the higher nervous activity similar to those observed in representatives of the strong type and often assuming an even more profound character. Several months after the onset of entirely chaotic activity there take place new changes of a cyclic character. For some time the dog's behaviour during the experiment becomes irregular and chaotic, and then a marked improvement sets in and it becomes more orderly for a certain period; in a few days it again assumes a chaotic character, after which it shows further improvement. With the passage of time this periodicity or cyclic course becomes increasingly manifest; the periods of better experimental work are more frequent and prolonged and the periods of chaotic work rarer and shorter until, gradually, everything becomes fully or relatively normal. Pavlov regards this phenomenon as a manifestation of the work of certain adaptive mechanisms in the organism.

"Of course," he said, "since we are acquainted with the system of endocrine glands, which to a certain extent help and supplement each other, it may be supposed that in the course of time the defect suffered by the organism immediately after castration is later more or less levelled out."*

Recovery of the higher nervous activity after castration sets in at different periods in different dogs: with some it takes place after several months, with others after several years; to a degree this depends on the peculiarities of the type of nervous system. We have already seen that the influence of the latter manifests itself with particular force in the first post-operation months: whereas

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 688.

the animals belonging to the strong nervous type display chaotic activity immediately after castration, the representatives of the weak type, on the contrary, for some time after castration work even better and in a more regular manner than before. Only some time later do chaotic disturbances of the higher nervous activity begin to develop in them, being in this case more persistent and assuming more violent forms.

Pavlov explains this temporary improvement in the following way: "When the sex glands of the animal are normal it experiences sexual stimulation; consequently, additional impulses reach the brain and tonify it; but the brain is weak. Hence the deficiency in the general nervous activity. With the removal of these glands the additional stimuli is lacking, the nervous system is eased and its work becomes in other respects more expedient. This is not a fantastic explanation. We find exactly the same in another, more tangible case. Take, say, a dog with one or another degree of appetite—this is of vital importance for our system of conditioned reflexes. If you have before you a strong dog and you increase its food excitability in one way or another (while experimenting with food reflexes), then all its conditioned effects are increased. With a weak type the opposite is the case. An increased food excitability generally causes the conditioned reflex to diminish, i.e., such additional excitation is insupportable for it and is accompanied by inhibition which we, therefore, term protective."*

Although in most cases it proved possible to attain total recovery of the higher nervous activity in castrated dogs, afterwards their nervous systems revealed a heightened fragility and susceptibility to injury. This was expressed in the fact that in such dogs nervous breakdowns and experimental neuroses developed with partic-

I. P. Pavlov, *Twenty Years of Objective Study*, p. 690.

ular ease—in many cases assuming a very severe and protracted character; as a consequence, castrated dogs have become one of the main objects of investigation in the field of experimentally induced disturbances of the nervous activity (especially phenomena of pathological inertness) and of experimental therapeutic investigations primarily concerned with the action of bromides on the nervous system.

The general disturbance which removal of the sex glands causes in the endocrine system, and consequently in the vegetative nervous activity and metabolism, plus the changes in the internal medium of the organism, complicate to a considerable degree the functioning of the higher parts of the central nervous system and make the nervous system much more susceptible to the influence of functional nervous traumas (collisions and breakdowns).

"It is quite clear that in those castrates, after their partial or total recovery, different neuroses could be produced more easily than in completely normal dogs because they have already been made to lose their equilibrium and naturally they are more fragile, so to speak, than normal dogs. In this way we can produce in them abundant different neurotic disturbances with the aid of the above noxious methods."*

In the last analysis, the nervous systems of all dogs subjected to castration suffer; both excitatory and inhibitory processes are affected, but the disturbances of the processes of internal inhibition are usually more pronounced than those of the excitatory process.

The consequences of castration are manifested in different ways depending on the type of nervous system; also of great importance are the age features, the peculiarities of ontogenic development, and in particular, the previous life experience impressed in the cortex. In strong

* *Ibid.*, p. 688.

young animals of the equilibrated and excitable types, after a certain period of disturbances caused by castration, the defects begin, gradually, to level out and the nervous activity is restored to normal. Weak inhibitable animals under usual conditions become more efficient after castration, but only temporarily; later they pay for their excessive work with a profound depression and drastic decline of efficiency.

A common feature of all castrated dogs is that at first they exhibit a more or less protracted and sharply expressed chaotic activity and then periodicity or circularity in their work.

Rest and the administration of bromide, as we shall see later, help greatly in restoring these animals to normal, but the reaction of the nervous system to bromide changes considerably after castration.

Somewhat related to the study of the influence of castration on the nervous system is the experimental investigation of changes taking place in the higher nervous activity of aged dogs, since here the hormonal action of the sex glands on the brain also gradually and progressively disappears, although, of course, the whole complex of noxious influences on the nervous system is here much more intricate.

A number of experimental investigations were devoted to the study of higher nervous activity in aged dogs (A. V. Tonkikh,* L. A. Andreyev, A. M. Pavlova, V. V. Yakovleva, O. P. Yaroslavtseva, M. A. Ussievich, M. K. Petrova, N. A. Podkopayev and others). Here, too, the processes of internal, active inhibition are the first to suffer; then the phenomena of passive inhibition are intensified (external inhibition, negative induction, transmarginal inhibition), and the conditioned reflexes decline, first the artificial, and then the natural ones, in

* L. A. Orbeli's co-worker.

succession. D. I. Soloveychik attempted (in 1932) to rejuvenate two aged dogs by ligating the spermatic duct, and also by transplanting a young testis into the scrotum (according to Voronov's method). Investigation of the higher nervous activity regularly carried out before and after each operation showed that the latter evoked a distinct increase in cortical excitability and an improvement in its efficiency; these, however, were of a temporary character and lasted only for about three months.

As demonstrated by the experiments conducted by A. V. Valkov (1925) the removal of the thyroid gland also results in abrupt changes in the dog's higher nervous activity.

A. V. Valkov subjected a number of puppies to thyroidectomy and some time later began to elaborate in them alimentary conditioned reflexes, which, however, developed with extreme difficulty. When in some cases they did appear towards the end of the experiment, they had to be elaborated anew during the next experiment, and this happened every day.

A stable conditioned connection was developed only by switching from food to acid reinforcement, but in these conditions it proved impossible to obtain even a crude differentiation. Only with the application of a stronger unconditioned stimulus in the shape of electric cutaneous reinforcement, was a persistent defensive motor conditioned reflex and a firm differentiation to it elaborated.

Thus the problem was solved only by sharply increasing the tone of the cerebral hemispheres. It follows from this that in young dogs subjected to thyroidectomy the excitatory process was plainly weakened and a still greater weakening of the processes of internal, active inhibition took place. Removal of the thyroid gland led to a considerable decline in cortical excitability.

M. K. Petrova, on the other hand, thoroughly investigated phenomena of chronic experimental hyperthyreosis induced in a number of dogs with the help of thyreiodin (1945). The following results were obtained: In dogs of the strong type the very first application of thyreiodin increased the excitatory process and greatly heightened the excitability of the cortex; this was manifested both in a considerable strengthening of the conditioned reflexes and in disinhibition of the differentiations. A protracted administration of thyreiodin (several months) resulted in a pronounced disturbance of cortical activity with a predominance of the excitatory process and with phenomena of general motor excitation. In the end, protracted administration of thyreiodin led to the development of nervous exhaustion; phenomena of transmarginal, protective inhibition, sometimes accompanied by phasic states and a rejection of food, came clearly to the fore.

In dogs of the weak type this inhibition appeared right after the first application of thyreiodin, owing to which here, instead of an increase, a drastic decline of conditioned reflexes was observed. Exorbitant excitation, surpassing the capacity of the weak cortical cells, resulted in the rapid development of phenomena of transmarginal inhibition.

Protracted administration of thyreiodin to dogs of this type led to a certain circularity in their higher nervous activity: periods of sharply expressed diffused protective inhibition were superseded by periods of fairly good efficiency.

In dogs of the strong type, but weakened as a result of castration, phenomena of periodicity or circularity rapidly developed after a transient initial increase in cortical activity; these were followed by chronic exhaustion of the cortical cells with complete and persistent decline in conditioned reflex activity.

Upon discontinuance of the thyreiodin, in a longer or shorter period of time (measured in months), the higher nervous activity, depending on the type of nervous system, was restored now more rapidly, now more slowly and protractedly.

L. O. Seewald (1940-1945) experimentally investigated the disturbance evoked in the activity of the cortex by removal of the parathyroids; these experiments were performed on dogs and lasted for several years. Seewald's conclusions are, essentially, as follows: extirpation of the parathyroids causes considerable deviations from normal conditioned reflex activity which becomes unstable and sharply diminishes; deviations are also manifest in derangement of the proper correlations between excitation and inhibition, consisting in weakening of the excitatory process and predominance of the inhibitory process, apparently of a secondary character.

The time of the onset of these disturbances, their severe course and duration depend on the amount of extirpated tissue (whether one, two or more glands), on the compensatory changes taking place in the remaining tissue, on the calcium content in the blood (hypocalcaemia) and on the character of the diet. L. O. Seewald is now working along these lines.

As far back as 1935 L. A. Andreyev and L. Pugsley published their work devoted to the influence of the hormone of the parathyroids on the dog's higher nervous activity. The administration of the hormone lowered the alimentary conditioned reflexes, strengthened successive inhibition, accelerated the process of extinction, developed phenomena of drowsiness and catalepsy and brought about a divergence of the salivary and motor reactions; in other words, the hormone led to a definite predominance of the inhibitory process over the excitatory. This inhibitory state was preceded by a temporary phase of heightened cortical excitability. The action of the

hormone on the conditioned reflex activity was effected through the rise of blood calcium evoked by it (hypercalcaemia). The experiments established a direct parallel between the changes in the calcium content of the blood and the state of cortical activity.

Investigating the action of large doses of pituitrin on the activity of the higher parts of the central nervous system, E. A. Asratyan (1935) observed in the animals a considerable lowering of alimentary conditioned reflexes, derangement of the proper correlations between the excitatory and inhibitory processes with a predominance of the latter, and a tendency towards higher unconditioned reflex activity. Thus it was proved that this hypophysial incretion greatly influences the work of the cerebral cortex and subcortical areas.

Similar results were obtained by A. A. Danilov (1940) who investigated the action of preparations of hypophysis on motor defensive conditioned reflexes in dogs; here, too, the predominance of the inhibitory process was the most pronounced of all disturbances of the cortical activity. In cases when for some reason the work of the cortex was weakened, these preparations, on the contrary, sometimes led to a temporary improvement in the conditioned reflex activity.

Investigations by D. M. Gizgizyan (1949) showed that partial removal of the adrenals in dogs caused a diminution of unconditioned and conditioned reflexes and the development of phasic phenomena in the cortex (equalization and paradoxical phases). Some animals exhibited a temporary increase of both unconditioned and conditioned reflex activity, accompanied by disinhibition of differentiations; however, here, too, there were observed phasic states (on the upper level). Gradual recovery of normal relations within the nervous system took place within six or seven months. But after another partial ex-

tirpation of the tissue of the adrenals complete recovery could not be attained even in a period ranging from one and a half to three years.

According to the experimental data of A. Y. Izergina (1947), the injection of large doses of adrenalin into the blood evoked in the animals, after a preliminary transitory phase of increased cortical excitability, phenomena of diffused inhibition, not infrequently involving phasic changes.

Thus, all the artificially induced endocrine disturbances described above led to considerable changes in the work of the higher parts of the central nervous system in animals. However, since in most cases the experimental investigation is still in its initial stage and provides but a sketchy description of these changes (only the consequences of castration have been thoroughly investigated), any attempt to sum up and generalize the above facts would be premature; it would also be absolutely erroneous to ascribe them to an increase or decrease of one or another hormonal influence on the nervous system, to discontinued or heightened secretion of one or another incretory gland. Actually, in all the cases described above we meet with qualitatively different and complex dissociations of the activity of the endocrine-vegetative system as a whole, in which now one, now another, incretory component of the disturbed functional system is accentuated.

The investigations devoted to endocrine disturbances bring us close to the problem of the influence of derangements in the vegetative nervous system on the higher nervous activity.

However, experimental data pertaining to this problem are still very scanty. All the more valuable, therefore, are the few investigations already carried out along these lines by E. A. Asratyan (1930-1935), B. V. Pavlov (1946), V. S. Deryabin (1946), M. F. Vassiliev (1946)

and N. N. Livschitz (1941). E. A. Asratyan extirpated in animals the superior cervical sympathetic ganglia and sectioned the cervical sympathetic trunks; this led to a lasting decline of the alimentary conditioned reflexes, to a predominance of the inhibitory process and development of phenomena of inertness. Complete recovery of the higher nervous activity was observed only after one year. The purpose of these experiments was to reveal the adaptive-trophic influence of the sympathetic nervous system on the cerebral cortex. Study of the restoration processes controlled by the higher parts of the nervous system would be of great importance.

B. V. Pavlov performed bilateral extirpations of the abdominal sympathetic chains in dogs, as well as the sectioning of their splanchnic nerves, after which he investigated the changes thus caused in the higher nervous activity of the animals. He came to the following conclusions: disturbance of the lower parts of the sympathetic nervous system leads to a change in normal correlations between the excitatory and inhibitory processes in the cortex with a predominance of the excitatory process; parallel with an increase of the latter, a decline of the inhibitory processes takes place.

Both the experimental data obtained by E. A. Asratyan and by B. V. Pavlov testify that qualitatively different disturbances of the cortical dynamics conform to differently localized lesions of the sympathetic nervous system.

The experimental work performed by N. N. Livschitz showed that the extirpation of the cerebellum, which, according to L. A. Orbeli, participates in regulating the activity of the vegetative nervous system, resulted in a change of conditioned reflex activity in dogs: the change resembled that caused by extirpation of the superior cervical ganglia in E. A. Asratyan's experiments.

V. S. Deryabin investigated disturbances in the activity of the higher parts of the dog's central nervous system caused by artificial (surgical) lesion of the thalamus and hypothalamic region. The disturbances manifested themselves in the following way: the alimentary unconditioned reflexes diminished, their latent period amounting to twenty-five seconds; the investigation of the conditioned reflexes revealed a drastic decline in the excitatory and inhibitory processes, but still with an obvious predominance of the latter over the former. There were also observed certain transient disturbances of the cutaneous, proprioceptive and optical reception, and also a considerable diminution of the animal's general mobility accompanied by an increase in the active defensive reaction to skin stimulation.

V. S. Deryabin maintains that the lesion of the vegetative centres in the hypothalamic area is responsible for the lowering of cortical excitability. Here, as in previous cases, investigation of the cortical regulation of restorative processes would be of indubitable interest.

M. F. Vassiliev elaborated in his dogs a number of alimentary, acid and local motor conditioned reflexes, at the same time registering general motor and respiratory reactions. Afterwards the anterior (propituitary) part of the hypothalamus was ablated in some dogs, in others—the posterior (postpituitary) part. In the first case the following stages were observed: 1) the *adynamic stage* (lasting from two to five days) which was characterized by general adynamia and sleep-like state; 2) the *depressive-chaotic stage* (lasting for two years and over) which revealed a considerable decline of alimentary unconditioned reflexes as well as of all previously elaborated conditioned reflexes, and the impossibility of developing new alimentary conditioned connections; during this state a strongly pronounced predominance of inhibitory processes came to the fore; 3) the *restorative stage*,

during which the functional defects in the activity of the nervous system gradually levelled out.

Several stages were also observed in dogs in which the posterior part of the hypothalamus had been destroyed; they are: 1) the *stage of motor excitation* having an explosive character (and lasting from two to five days); 2) the *rhythmic exaltation stage* (lasting from one and a half to two years) during which all conditioned reflexes increase and new conditioned connections are very rapidly formed; 3) the *restorative stage* characterized by a return to pre-operation normalcy.

Basing himself on his experimental data, M. F. Vassiliev drew the conclusion that the anterior part of the hypothalamus tones up the cerebral cortex and exerts a regulative influence on it, intensifying its adaptive capacity; on the contrary, the posterior part of the hypothalamus exerts, under normal conditions, an inhibitory influence upon the cortex.

Obviously, all these considerations are of a strictly preliminary character, since experimental work in this field is still in progress.

The experimental data obtained by E. A. Asratyan, B. V. Pavlov, V. S. Deryabin, M. F. Vassiliev and N. N. Livschitz reveal the pathological changes which take place in the higher nervous activity of animals under the influence of differently localized lesions of the vegetative nervous system; thereby they unveil the extremely complex and hitherto little-investigated changes of the nervous relations between the cortex and the vegetative nervous system in different pathological conditions.

In conclusion, it is impossible not to mention an extremely interesting phenomenon. We know that restriction of the access of external stimuli to the cerebral cortex by artificially cutting off one or a number of external receptors (A. D. Speransky and V. S. Galkin, K. S. Abuladze, O. S. Rosenthal) resulted in a consider-

able predominance of the inhibitory process over the excitatory; but we also know that exactly the same thing is observed under the action of excessively strong, superpowerful or summated stimuli (V. V. Rickman, L. O. Seewald, G. V. Skipin, V. V. Yakovleva and others). It is obvious that a similar phenomenon is observed also under the action of internal stimulation: derangement of cortical activity caused by partial or complete extirpation of the different endocrine glands (sex, thyroid, parathyroid and adrenal), which normally exert a stimulatory action on the cortex and, in the final analysis, manifest themselves in the development of inhibitory states in the cortex; but injection of large doses of incretions belonging to the same glands, or their excessively prolonged administration, also leads to a predominance of the inhibitory process over the excitatory and to phenomena of diffused inhibition in the cortex.

Thus, in a number of cases weakening of the impulses reaching the cerebral hemispheres from the organism's internal medium, and, on the contrary, their artificial intensification, produced similar results despite the divergent conditions.

Unfortunately, all the works described or cited above, devoted to the problem of the influence on cortical activity of lesions experimentally induced in the vegetative nervous system, do not contain any clear or accurate indications as to the leading role of the cerebral cortex in the activity of the vegetative nervous system, nor do they reveal the regulating influence of the cortex on this system. And yet study of the adaptive cortical mechanisms, which could help in eliminating artificially induced disturbance of the vegetative functions is of great interest; of similar interest is the study of those restorative processes which could disclose the role of cortical regulation of vegetative functions under pathological conditions.

9

PATHOLOGICAL CHANGES OF THE HIGHER NERVOUS ACTIVITY RESULTING FROM VARIOUS FORMS OF EXPERIMENTAL INTOXICATION AND FROM CERTAIN INFECTIONS

As far back as 1914, N. A. Podkopayev, one of Pavlov's oldest co-workers, performed the following experiment on a dog: combining a repeated hypodermic injection of apomorphine with the sound of an organ-pipe, he finally transformed this auditory stimulus into a conditioned signal of a nauseous and vomitive reaction, which at first had been obtained by him with the help of apomorphine. The vomiting centre of the brain stem, which had been *automatically* stimulated via the blood, that is, in a neuro-humoral way, now could be set into action also through the cerebral cortex, that is, by means of a conditioned reflex.

Similar experiments were later made in one of the Pavlov laboratories by V. A. Krilov. Each day he injected morphine into the experimental dogs; after five or six days he noticed that the injection preliminaries began to produce a reaction identical with that produced by the injected morphine, i.e., a profuse secretion of saliva, nausea and vomiting. Thus, all external stimuli which directly preceded the injection of morphine and coincided in time with its appearance in the blood became conditioned stimuli producing the same effect as the morphine itself.

Describing these experiments of N. A. Podkopayev, which were further advanced by V. A. Krilov, Pavlov said: "This experiment provides a clue to the well-known fact that, for example, dogs, after removal of their parathyroids or after an Eck fistula and tying of the portal vein, will eat meat only the first time it is offered them,

and on all subsequent occasions refuse it. Evidently, in these cases the appearance and smell of the meat evoke in them a certain pathological reaction identical with that produced in them by meat poisoning under the above-mentioned conditions, and thus cause their negative reaction to meat."*

Considering the underlying nervous mechanism of N. A. Podkopayev's experiments, which were corroborated by the experiments of V. A. Krilov, Pavlov stated: "All these experiments bring us to the question of the process by which a new nervous connection, a new nervous coupling is effected. It is not difficult to suggest an explanation on the basis of actual facts. Any unconditioned, or any firmly established conditioned stimulus undoubtedly evokes an active state of some definite part of the brain. Using the generally accepted terminology, let us refer to such a part of the brain as the *centre*, however, not implying thereby any idea of strict anatomical localization. Evidently, the stimulations simultaneously effected in the cortical cells of the cerebral hemispheres by external agents are conducted to this centre; the path by which they are conducted to this centre is particularly eased and after several coincidences it becomes well marked out. This is the only possible interpretation of the facts. Proceeding from this interpretation, we planned the above-described experiment with apomorphine, later so thoroughly corroborated by the experiment with morphine. If the stimulation set up in the cells of the cortex is transmitted to the reflexly excited centre, a precisely similar phenomenon must take place when the centre is stimulated automatically, by internal agents, by the composition and properties of the blood. This was fully justified in the sequel."**

* I. P. Pavlov, *Lectures*, p. 42.
** *Ibid.*, pp. 42-43.

The influence of the cortex upon the bulbar centres of the vagus, observed and described by A. I. Smirnov, and the fact that this nerve is represented in the cortex, bring us to the assumption that the temporary conditioned connection in question is linked in the cortex.

Many experimental investigations based on the same principle which underlies N. A. Podkopayev's experiments (i.e., on the principle of developing a conditioned connection with the help of an automatic neuro-humoral unconditioned stimulus acting through the blood) were carried out by K. M. Bykov's collaborators (V. E. Delov, R. P. Olnianskaya, A. M. Borodavkina, E. G. Petrova, G. A. Samarin and others).

However, all these valuable investigations presented mostly fragments of the single problem of interrelations between the cortex and the internal organs; their principal purpose was to show the diversity and the unlimited possibilities of cortical influences on the work of various internal organs and on the course of different physiological processes in the internal medium.

Meanwhile N. A. Podkopayev's experiments, along with the wide physiological prospects which they opened up, were also of patho-physiological significance, a point not sufficiently realized nor stressed at the time by N. A. Podkopayev himself, but which, nevertheless, did not escape the keen mind of the founder of the theory of higher nervous activity. Recalling in connection with these experiments the dogs with the extirpated parathyroids and with Eck fistulas, Pavlov, as we have just seen, pointed out that phenomena of *intoxication* may be caused by conditioned stimuli connected with them.

This problem, which is of extreme importance for pathology, attracted the attention of A. O. Dolin who, since 1937-1938, jointly with his collaborators (I. I. Zborovskaya, E. P. Nikitchenko and others) has been engaged in its special elaboration. Employing toxic doses

of such substances as aconitine, morphine, apomorphine, dinitrophenol, camphor and bulbocapnine, A. O. Dolin developed in the animals pathological phenomena of morphine intoxication, morbid disturbances of the cardiovascular system (aconitine), fever and such syndromes as epileptiform seizures, catalepsy and catotonic stupor. Although the pathological states, caused by the introduction of the above-mentioned toxic substances into the blood, present, in A. O. Dolin's view, responsive reactions of an unconditioned character, they still substantially differ from the usual unconditioned reflexes, being qualitatively specific nervous integrations—pathological integrations.

Regularly combining artificially induced pathological states with external stimuli (gurgle of water, sound of a whistle, drone of an engine, rotation of an electric whirling, etc.) A. O. Dolin obtained peculiar pathological conditioned reflexes which presented, as it were, models of morbid symptoms complices, of various pathological syndromes. For example, by means of morphine intoxication he obtained a complex of symptoms which included conditioned reflex dyspnoea, a conditioned toxic leucocytosis, a conditioned vomitive reflex, etc.

The rotation of an electric whirling, repeatedly combined in time with hypodermic injections of aconitine, began to produce a conditioned reaction involving derangement of respiration and blood pressure, as well as a strong arhythmia, with the pulse rate increased by thirty to forty beats per minute.

From six to eight applications of an unconditioned stimulus in the form of injection of bulbocapnine in combination with the action of a conditioned stimulus (the appearance and gurgle of water in a vessel) proved sufficient to impart the significance of a morbific agent to the conditioned stimulus; now it produced in the dog very marked phenomena of catalepsy (waxy rigidity) similar

to those obtained by the bulbocapnine injection. In this way it was possible to obtain phenomena of conditioned catalepsy.

A conditioned convulsive fit possesses certain peculiarities distinguishing it from other pathological states. Combining a distance receptor stimulus (the appearance and sound of an electric whirling) with a camphor injection, subcutaneously or by means of a probe direct into the dog's stomach, the experimenter obtained only a fit of minor epilepsy; but applying a contact receptor stimulus in the form of hypodermic injection of physiological solution or administration of liquid oil not containing camphor, into the stomach by means of a probe, he succeeded in obtaining major convulsive fits, sometimes even more violent than those produced by giving camphor.

These investigations showed that under certain conditions the cortex can evoke, through the mechanism of a pathological conditioned connection, a complete derangement of the organism's vegetative and somatic activity and thus reproduce the picture of acute intoxication. In other investigations A. O. Dolin, on the contrary, sought to reveal the curative tendencies of the cortical interference with such experimental intoxications, to disclose the ability of the cortex "to come to the rescue" of the organism in its struggle with morbific agents.

By elaborating conditioned inhibitors in the usual way, A. O. Dolin obtained with their help not only the inhibition of conditioned morphine reflexes, but also the suppression of the effect produced by the unconditioned action of toxic doses of morphine. Subsequently, he also endeavoured to show that the action of toxic substances can be suppressed by the elaboration of a simple cortical dynamic stereotype. After fifty or sixty hypodermic injections of physiological solution, always accompanied by drinking milk at intervals of fifteen minutes, the physiological solution was abruptly replaced by a toxic dose of

morphine solution; in these cases the dog's reaction to morphine was confined merely to a transient change of the respiratory rhythm, coinciding in time with the moment of the usual action of the injected morphine; but the expected vomiting and toxic dyspnoea were not observed at all.

As shown by A. O. Dolin's experiments on adult animals and on puppies and young rats, such physiological states as pregnancy or starvation and also age features, while changing the general reactivity of the organism, simultaneously change its reactions to all the above-mentioned toxic agents, which in A. O. Dolin's experiments served as the basis for raising, using his terminology, the *special* conditioned reflexes to a pathological state.

However, it should be said that quite a considerable number of authors approached the important problem of the role of the cortex in the organism's pathological processes, and in particular those caused by intoxication and infection, in a way different from that observed in the interesting experiments of A. O. Dolin.*

In the Pavlov school the problem of various toxic influences on the animal's cerebral cortex first became the object of special investigation by M. K. Petrova in the early thirties. "There are many instances," she wrote in 1935, "when bromide, being most injurious to weak dogs, not only does not improve the picture, but, on the contrary, makes it worse; while intensifying inhibition in those dogs, the bromide does not bring it to the level of concentration, but only increases the irradiation of inhibition, thus still more aggravating the hypnotic state.

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* A. A. Kanarevskaya (in A. D. Speransky's laboratory) repeatedly injected horse serum into a dog and observed that shock phenomena began to appear the moment the needle entered the vein, i.e., assumed a conditioned reflex character. These observations concur with A. O. Dolin's investigations.

Besides, by intensifying the inhibitory process, bromide, as we know, in conformity with the laws of induction, strengthens the excitatory process and this cannot be endured by such a weak nervous system as that of our Hop (the dog's name); as a result, under the influence of bromide, the reflexes, after reaching peak, decline to a still greater degree or even completely disappear, and the differentiation becomes disinhibited (possibly owing to overstrain of the weak inhibitory process...)."* Accordingly, the therapeutic doses of bromide accepted by the laboratory proved to have a toxic effect on dogs of the weak type of nervous system (of which further mention will be made).

We have already dwelt on the chronic experimental neurotoxicosis thoroughly studied by M. K. Petrova and obtained by her in dogs as a result of protracted administration of thyreiodin. Other experiments conducted by M. K. Petrova showed that excessive (toxic) doses of calcium chloride, due apparently to overstrain of the processes of internal, active inhibition, lead to a pathological predominance of the excitatory process; this finds expression in violent motor excitation of the animals and ends in phenomena of cortical exhaustion with a progressive decline of the conditioned reflex activity and phasic phenomena (transmarginal inhibition).

M. K. Petrova subjected to a very detailed study the phenomena of chronic alcohol intoxication in dogs. Here first of all a gradual weakening of the processes of internal, active inhibition was observed, and then the excitatory process, too, began little by little to weaken; at the same time lingering phasic states set in, one superseding the other, testifying to the development of phenomena of protective-transmarginal inhibition.

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* M. K. Petrova, *Latest Facts Relating to the Mechanism of the Action of Bromides on the Higher Nervous Activity*, All-Union Institute of Experimental Medicine, 1935, p. 51

Diffused cortical inhibition positively induced the subcortical regions, which were intoxicated in their turn, and this caused an increase and dissociation of the complex unconditioned reflex activity (the strengthening now of the defensive, now of the aggressive, now of the alimentary or some other complex unconditioned reflex).

However, owing to continued and progressing intoxication, the transmarginal inhibition did not assume considerable stability and intensity, as though breaking down and revealing its insufficiency; at first this was expressed in the appearance of pathological lability (excitatory weakness) of the cortical processes, and later in phenomena of pathological inertness accompanied by unusual reactions of the animals, resembling phobias and hallucinatory behaviour.

It should be stressed that in the course of her research into intoxications M. K. Petrova paid much attention to the diversity of reactions connected with the typological features of the dogs; she found that intoxications assumed the most severe forms in dogs of the weak and unequilibrated types.

As far back as 1935, I. S. Tsitovich, conducting comparative toxicological experiments on various animals (dogs, cats, rabbits, rats, mice and birds), became interested in the action of acetone and later of benzine vapours on the higher nervous activity. Corresponding experiments were carried out by him on dogs in which motor alimentary conditioned reflexes to auditory stimuli, as well as differential inhibitors, had been previously elaborated. The animals were placed in a special chamber—a cistern into which acetone vapours of varying concentration and time of action were admitted. Under very high concentrations the toxic effect was expressed in the complete disappearance of conditioned reflexes (and consequently of the differentiations as well), and in the development of drowsiness. After the experiment derangements

of equilibrium (disturbances of the subcortical activity) were observed. The differentiations were the last to recover.

Under prolonged action of subtoxic doses (lasting for many hours) the processes of internal inhibition suffered first (disinhibition of the differentiations); later on phasic phenomena arose (the ultra-paradoxical phase). There were also observed various vegetative disturbances (Veshchezerov, Olshansky, Sukhov and others). Under the action of subtoxic doses of benzine vapours a decline of the processes of internal inhibition was also the first to manifest itself.

Similar investigations were conducted by Y. P. Frolov and his collaborators (Gorsheleva, Trinkin, Polyansky and others). Here, too, comparative toxicological experiments were performed (on lizards, birds, rats, rabbits, etc.). The influence of chronic toxicoses caused by sodium cyanide and carbon oxide on the higher nervous activity of dogs (these investigations were carried out with the help of the salivary method) and of rats (with the help of the motor method) was studied with the utmost thoroughness.

In both cases of intoxication first of all the processes of internal inhibition were affected. Under cyanide intoxication there was observed a preliminary stage of disinhibition of the internal inhibitors, followed by a steady decline of the conditioned reflexes, by apathy, drowsiness and sleep, i.e., by phenomena of diffused inhibition in the cerebral cortex. There were also phenomena of pathological inertness of the excitatory process. In severe cases torpid, incurable eczemas set in.

Carbon oxide poisoning first led to the weakening of the processes of active internal inhibition and then to the development of phasic states under which the disturbances of cortic activity acquired a circular character. Not infrequently subcortic disturbances seemed to inter-

pose in the picture of intoxication; they were particularly manifest under the action of cyanides and were expressed in the unnatural and strange behaviour of the animals (for example, in attempts to lick a burning match or to crawl into narrow, dark places). Disorders of the vegetative functions were also clearly noticeable.

Animals of the strong and equilibrated types of nervous system proved to be most resistant to cyanide or carbon oxide intoxication.

Of considerable interest are the experimental investigations conducted for a number of years (1935-1941) by V. S. Deryabin and devoted to the action of bulbocapnine upon the dog's higher nervous activity; as is known, the toxic action of the bulbocapnine manifests itself mainly in the development of catatonic states. Administration of bulbocapnine led first of all to inhibition of the salivary conditioned reflexes, no motor disturbances being observed. Further observation showed that under the action of progressively increased doses of bulbocapnine phenomena of cortical inhibition developed in strict succession: first the artificial alimentary conditioned reflexes were inhibited, then the natural ones, later the acid reflexes, and finally, the motor defensive reflexes (elaborated with the help of an electric cutaneous reinforcement). V. S. Deryabin points out that the conditioned reflexes proved to be more stable when their underlying unconditioned stimulus was stronger.

Catatonic phenomena could be observed already under incomplete inhibition of the cortex, when the acid and motor-defensive conditioned reactions were still in evidence. Bulbocapnine catatonia developed in the following forms: general hypokinesia, stupor, petrifaction in aphysiological postures, catalepsy, negativism. All these phenomena developed on the background of progressive diffused inhibition of the cerebral cortex.

At a certain level of intensity and extensity of this

inhibition the unconditioned defensive reflexes began to free themselves from the regulating influence of the cortex; at first this was expressed in passive resistance to any attempt to change the animal's posture, and then in gradually increasing active defensive reactions not only to the touch of strangers, but also of the laboratory personnel; this was accompanied by inhibition of the previously positive reactions to it. Under the action of very large doses even these defensive reactions vanished, reappearing for a certain time during the reverse development of the picture of intoxication. The action of bulbocapnine is not confined to the brain; it extends also to the spinal cord, which to a certain degree is responsible for the development of motor disturbances. It should be admitted that the experimental catatonia obtained by V. S. Deryabin closely resembles the various syndromes of clinical catatonia and is of great help for an understanding of its nervous mechanisms.

The experiments of N. V. Vinogradov (1946) showed that the administration of small doses of bulbocapnine first of all evoked inhibition of the motor alimentary conditioned reflex which had been elaborated to the stimulation of the skin by means of an electric current. Along with the inhibition of this conditioned connection, there was observed a disinhibition of the previous unconditioned defensive reaction to the same stimulus.

A series of investigations were carried out in our laboratory in 1946-1948 with the aim of studying the disturbances of the higher nervous activity caused by various toxic agents, as well as disturbances of an infectious-toxic origin (L. I. Kotliarevsky, L. S. Gorsheleva, L. E. Khozak, A. Y. Izergina, V. K. Faddeyeva).

However, the chief purpose of these experimental investigations was not to characterize the specific properties of the action of one or another noxious agent, but rather to study the basic and most general reactions

(or, more precisely, the forms of reaction) of the higher parts of the central nervous system to various toxic and infectious-toxic influences of a neurotropic nature, which act on the brain through the blood and reach the brain from the organism's internal medium in an interoceptive way.

Consequently, we were interested not only in the peculiarities of the reactions of the nervous system to one or another noxious agent applied by us, but also in the common features of all such reactions, irrespective of their more or less marked and even striking distinctions.

In view of the complexity of our task we decided to confine our experimental work in the initial stage to relatively simple objects of investigation—white rats and guinea pigs; for this purpose we worked out special methods of studying the motor defensive and motor alimentary conditioned reflexes. Experimental work within the chamber was invariably combined with regular observation of the changes in the animals' general behaviour outside the chamber.

The experiments carried out by L. I. Kotliarevsky showed that hypodermic injections of bulbocapnine evoked in rats a fleeting motor excitation, which was gradually superseded by complete immobilization and petrifaction in a flexuous posture; this was accompanied by strongly pronounced phenomena of catalepsy which sometimes developed into general stupor with passive resistance to all attempts to change this state. In these circumstances first the conditioned (defensive) reflexes disappeared and then the unconditioned (nociceptive, alimentary and orienting) reflexes. This state persisted for several hours, after which the animals' general behaviour returned to normal, without revealing any obvious deviations from it. But the experimental investigations showed that during the subsequent three to five days the artificial conditioned connections elaborated in the rats

were still in a state of inhibition, at first complete, and later—in the shape of phasic states; the processes of internal, active inhibition (differentiations) were the last to recover.

The experiments conducted by L. S. Gorsheleva showed that, as a result of intoxication caused in rats by the administration of tetraethyllead, first of all the processes of active (differential and extinguishing) inhibition were affected; this took place on the background of a general increase of excitability (it is interesting to observe that at this stage of intoxication the duration of the daily sleep of the animals increases, reflecting, apparently, the compensatory tendencies of protective inhibition). The stage of heightened and accelerated alimentary conditioned reactions and disinhibited differentiations is superseded by phasic states and, finally, by complete (transmarginal) inhibition of the conditioned reflex activity. With the application of relatively small doses this is followed by a reverse development of the pathological picture; with the application of large doses there arise, on the background of diffused cortical inhibition, phenomena of clearly marked subcortical excitation; at first these are characterized by an increase of all the unconditioned reactions and then, probably owing to inhibition of the highest of them, by dissociation of the subcortical activity and disinhibition of unusual reactions, not peculiar to rats and, to a certain degree, bearing what would seem to be a rudimentary character. At this stage, being in a state of general motor excitation and refusing to eat, the rats accumulate and hide the food, exhibit an extremely aggressive attitude towards one another and towards the attendants (biting and scratching them) and, not infrequently, devour their young. Later, the inhibition spreads farther and farther over the brain stem, leading to general immobilization and finally to a comatose state (sometimes accompanied by convul-

sions) which ends in death. The whole picture develops in the space of a few days.

In the experiments of L. E. Khozak the injection of mescaline evoked in guinea pigs, after a transient stage of mainly vegetative excitation (quickened rhythm of respiration, vomitive movements), a rapid development of general immobilization with intensified passive-defensive reactions and petrifaction in various aphysiological postures (normally they are not inherent in these animals and probably were accounted for by the hallucinatory phenomena usually produced by mescaline). In these conditions there was observed a complete disappearance of both artificial and natural alimentary conditioned reflexes and a stubborn rejection of food. In most cases these disturbances in the general behaviour disappeared in a day or two, and the animals no longer showed any deviation from normal. But disturbances of the higher nervous activity could still be observed in the course of experimental investigation over a period of several months; sometimes they assumed the character of periodic, circular fluctuations and in most cases took the shape of protracted phasic states superseding one another (before intoxication they had never been observed in the animals). Here, too, the disturbances of the processes of internal inhibition (differential and extinguishing) were most persistent. Rehabilitation of the higher nervous activity could be attained only after a course of special treatment.

In the experiments of A. Y. Izergina the application of toxic doses of adrenalin evoked in rats first a state of heightened cortical excitability and disinhibition of differentiations, then a picture of diffused inhibition, and, in the course of the reverse development of the intoxication, again a state of heightened excitability.

Using toxic doses of phenamine which, however, produce reverse disturbances of the nervous activity, and

applying the same alimentary method, V. K. Faddeyeva obtained in rats a similar picture: an initial increase of excitability, rapid transition of the cortical cells to a state of transmarginal inhibition with phasic phenomena, further extension of inhibition to the subcortical (unconditioned) reflex activity, and again phenomena of heightened cortical excitability with weakened processes of active inhibition during the period of the reverse development of the intoxication. But on application of lethal doses of phenamine in the experiments of V. K. Faddeyeva there were observed the same strongly pronounced derangements of the subcortical activity as caused by the tetraethyllead intoxication in the experiments of L. S. Gorsheleva. At first on the background of growing diffused cortical inhibition there was observed an intensification, an activation of complex unconditioned reactions (an accelerated process of eating, heightened orienting and defensive reactions), then their gradual inhibition and the emergence of monotonous, stereotype, iterative movements; this was followed by anteropulsions, retropulsions and circus movements, and finally, by convulsive, mostly tonic, phenomena; still later there arose a comatose state and general atonia, ending in death. Thus, with the gradual extension of inhibition to the deeper levels of the brain stem and with the disappearance of the regulatory influences of the higher parts upon the subordinated lower parts, the functions of the still lower levels of the brain stem became liberated, disinhibited and at the same time dissociated; this continued until the vital nervous centres stopped functioning.

In recent years our laboratory has also thoroughly studied the disturbance in higher nervous activity obtained by experimental intoxication of animals with staphylococcal, streptococcal, diphterial and typhoid toxins (Kotliarevsky, Karpenko, Gorsheleva, Khozak and others), as well as disturbances of the higher parts of

the nervous systems of animals under allergic states (Khozak).

Comparing the pictures of intoxication described above, we can draw the following conclusions:

1. Disturbances of internal, active inhibition are usually the first to emerge and the last to disappear; according to Pavlov, this inhibition is one of the basic properties of cortical activity and, consequently, is the evolutionarily younger form of nervous inhibition, which, apparently, accounts for its particular fragility and susceptibility to injury.

2. In most cases there is observed now a fleeting, now a protracted and sharply expressed stage of heightened cortical excitability involving disinhibition of the active inhibitors.

3. In all cases there are observed at the height of the intoxication phenomena of diffused cortical inhibition with phasic states; under some neurotoxicoses they are manifest in the period of the progressive development of the disease, in others (where general inhibition sets in very rapidly) in the period of its reverse course, sometimes considerably protracted.

4. This diffused, irradiating inhibition, which in Pavlov terminology belongs to the group of passive forms of inhibition, is mainly a transmarginal, protective inhibition, which, however, does not preclude the development of other forms of the inhibitory process.

5. At first embracing the youngest artificial conditioned connections and then also the natural conditioned reflexes, this inhibition under all the intoxications investigated by us tends to spread to the unconditioned reflex activity, that is, to subcortical activity. Thus, the inhibition spreads from the evolutionarily youngest forms of nervous activity to its oldest forms.

6. Certain disturbances of the subcortical functions

were observed under all the neurotoxicoses investigated by us.

7. Derangement of normal relations between the cortical and subcortical activity were also observed in all cases.

The main qualitative distinctions of the neurotoxicoses were expressed: a) in the peculiarities of the dynamics of development of the cortical disturbances; b) in the general nature of the disturbances of the subcortical activity; c) in the peculiarities of dissociation which took place in the joint activity of different parts and functional systems of the brain. The complex of all these neuro-dynamical disturbances found external expression in pathological changes of the general behaviour.

Other conditions being equal, the intoxications usually took a most favourable course in representatives of the strong, equilibrated types of nervous system (L. I. Kotliarevsky, L. E. Khozak, L. S. Gorsheleva, A. Y. Izergina).

We also devoted attention to the influence exerted on the course of intoxication by nervous breakdowns and by overstrain of the nervous processes, which are evoked by difficult experimental tasks and are simplified models of "psychical traumas."

For this purpose we performed experiments on two groups of animals; each animal of the first group was subjected to a nervous breakdown and experimental neurosis, in the course of which the intoxication was effected; the animals of the other, control, group were subjected to intoxication without any preliminary collisions and breakdowns.

The experiments conducted by L. I. Kotliarevsky (with bulbocapnine), L. S. Gorsheleva (with tetraethyllead) and L. E. Khozak (with mescaline) showed that in nearly all the animals subjected to preliminary collisions and nervous breakdowns, the course of toxicosis was much more serious and protracted than in the con-

trol animals. Thus, the influence of severe external conditions ("psychogenic moments") on the course of toxicoses clearly manifested itself.

V. K. Faddeyeva and A. Y. Izergina jointly investigated the disturbance in the higher nervous activity of animals brought on by toxic processes of infectious origin. For this purpose they selected rats suffering from so-called pasteurellosis, a disease with phenomena of suppurative, steadily-progressive pneumonia, often found in these animals and usually ending in their death. Here, too, initial disturbances of internal inhibition were observed, followed by the development of phasic states, and the gradual disappearance first of the artificial and then the natural conditioned reflexes.

It should be pointed out that much earlier (in 1933) O. P. Yaroslavtseva carried out experiments on a dog suffering from inflammation of joints; she described the development of a long pathological state with phasic phenomena, dissociation of the motor and secretory reactions and other disturbances of cortical activity; she attributed this pathological state to phenomena of external inhibition evoked by pathological stimulations emanating from the affected joints. But even in this case toxic influence on the cerebral cortex can hardly be doubted. It is quite possible that a combination of phenomena of protective and external inhibition takes place in the course of many somatic diseases.

Thus, we have seen that the systematic study of pathological states of the higher nervous activity caused by various noxious functional (i.e., not crude, mechanical) influences on it, which was started in the Pavlov laboratories in the early twenties, has been steadily and progressively developed, gradually extending in breadth and depth and embracing ever new fields of activity.

In 1930 Pavlov stated: "In our experimental animals (dogs) we have already obtained obvious experimental

neuroses as well as means for treating them. . . . Now it seems to us quite feasible also to develop in the same animals phenomena somewhat analogous to those which in human beings are termed psychoses."*

Indeed, it proved possible to create in the laboratory not only experimental (though roughly simplified) models of neurotic syndromes, but also models of different (in particular, toxicogenic) psychotic states ("experimental psychoses"). At the same time it proved possible to reproduce similar models not only of psychogenic, but also somatogenic pathological situations, by switching from difficult experimental tasks in the external environment to difficult experimental tasks artificially created in the internal medium of the organism.

Hence, the sphere of experimental investigation included pathological changes in higher nervous activity under endocrine disturbances, lesions of the vegetative nervous system and, finally, under intoxications and infections. It is now possible, though still on a small scale and in rudimentary form, to investigate the interaction of external and internal noxious influences upon the nervous system emanating from the surrounding world and the internal medium of the organism. New and broad vistas, vastly extending the bounds of the patho-physiology of the higher nervous activity, open up before the research worker.

We already know that a basic feature of this branch of science, as stressed by Pavlov, is its striving to investigate not only pathological disturbances together with their sources and underlying pathogenic nervous mechanisms but also the means for their elimination.

We now turn to problems connected with experimental therapy of pathological states of the higher nervous activity.

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 509.

10

EXPERIMENTAL THERAPY OF DISTURBANCES OF THE HIGHER NERVOUS ACTIVITY CAUSED BY VARIOUS NOXIOUS FUNCTIONAL INFLUENCES

The first attempts to treat experimental neuroses were made simultaneously with their first investigations (M. K. Petrova, V. V. Rickman, O. S. Rosenthal, E. M. Kreps and others). Together with the advance of the theory of pathological states of the higher nervous activity, evoked by various noxious functional influences, progress was made in experimental treatment of them.

Earlier, when dwelling on experimental neuroses, we repeatedly, although in passing, mentioned the attempts aimed at their treatment.

These consisted first of all in different measures designed to ease the conditions of the experimental work on the animals and to provide them with rest.

After a nervous breakdown and the development of a more or less protracted pathological state, the positive and inhibitory stimuli, responsible for the collision and overstrain of the cortical processes, were deliberately excluded from the experiments (for a longer or shorter period of time). In cases of breakdowns of an excitatory character, the animals were for some time fully released from the application of internal inhibitory agents; in cases of breakdowns of an inhibitory character, the conditioned stimuli were often transformed from delayed into almost concurrent ones (for example, the reinforcement was administered not in the usual thirty seconds, but in five). In some cases all previous conditioned stimuli were replaced by new ones.

In 1948, when studying the influence of changes in environment on the higher nervous activity of dogs,

V. V. Stroganov reached the following conclusion: "In the course of experiments performed alternately in two chambers a drastic decline in the strength of the elaborated conditioned reflexes was observed in all dogs during the first period of experimental work in a new chamber; in all dogs the temporary inhibition of conditioned reflexes caused by the new environment was superseded by a lasting and considerable increase of all conditioned reflexes of the stereotype; at the same time the increase in the conditioned reflexes in the new chamber exceeded not only the average increase in them during the previous experimental work in the old chamber, but also those obtained in it in the process of interchanging chambers."* Although these data have not yet found any application in the field of experimental neuroses, they, nevertheless, deserve close attention from the point of view of their utilization in the treatment of pathologically disturbed higher nervous activity.

One of the oldest methods of improving the work of the cerebral cortex--in circumstances of steadily diminishing conditioned reflexes and phenomena of irradiating inhibition and drowsiness—consists in alternating the positive and inhibitory conditioned reflexes (differentiations, conditioned inhibitors), which, through the mechanism of induction, intensifies the concentration of both the inhibitory and excitatory processes (the diffused inhibition is, as it were, broken up and interchanged with excitation). There are a number of indications showing that proper optimal recesses between the applied conditioned stimuli also promote the restoration of diminishing conditioned connections (M. K. Petrova, S. I. Galperin, A. A. Lindberg and others).

Sometimes extinction of the first of the successive conditioned reflexes applied during the given experi-

* Collected Papers of the I. P. Pavlov Physiological Laboratories, Vol. XIII, 1948, p. 148.

mental day was also practised (M. K. Petrova, V. I. Pavlova).

With the development of phasic states all strong stimuli, as well as all previously applied internal inhibitors, were often excluded from the experiments.

As proved by a number of investigators, one of the powerful factors contributing to the successful accomplishment of the difficult experimental task by the animal and to the elimination of its neurotic state is gradual and careful training of the animal for the accomplishment of easier or analogous tasks; this training leads, slowly but surely, to the successful fulfilment of the first task which previously was responsible for the overstrain of the cortical processes and the nervous breakdown (M. K. Petrova, V. V. Yakovleva, O. P. Yaroslavtseva, M. A. Ussievich, A. G. Ivanov-Smolensky and others).

An interesting and successful attempt to cure "isolated pathological points" was made by S. V. Klestchov, and later by M. K. Petrova. In the course of a number of experiments they subjected the local disturbance to the action of external inhibition (negative induction) caused by a new and strong stimulus, by stimuli relating to the same analyser or by the application of an unconditioned stimulus coinciding with the conditioned one (counter-attractive therapy).

Besides relieving and renovating the conditions of the experiments, besides thoroughly "sparing" the disturbed dynamic structures by leaving them in a state of peace, and training the animals for the accomplishment of easier tasks, the experimenters widely practised partial or complete discontinuance of the experimental work with a more or less long period of rest for the animal.

In some cases the experimental work was conducted not every day, as usual, but every two or three days, until the animal's higher nervous activity fully recovered;

in other cases it was completely discontinued for one or two months and sometimes for an even longer period.

All the above measures were applied to different forms of experimental neuroses; they were applied with the greatest frequency during experiments with castrated dogs. Since overstrain of cortical processes, collisions and nervous breakdowns with their resulting pathological states were observed most frequently in castrated dogs, many therapeutic methods were first tested and thoroughly elaborated on these animals.

It should be said that, while attaching great importance to rest and training in the treatment of experimental neuroses, Pavlov devoted no less attention also to medicamentous measures, to which we now turn.

The action of bromide on the higher nervous activity of dogs was first investigated by P. M. Nikiforovsky as far back as 1910. Nikiforovsky was the first to prove that bromide is conducive to the elaboration of differentiations. And since differential inhibition was regarded as a phenomenon of internal inhibition, the positive action of bromide on the processes of internal inhibition was thus established.

The action of bromides (sodium bromide was used more frequently, potassium bromide more rarely)* on cortical activity was subjected to a particularly elaborate investigation in connection with the treatment of experimental neuroses and disturbances caused by castration (M. K. Petrova, V. V. Rickman, V. V. Yakovleva, O. S. Rosenthal, M. A. Ussievich, S. I. Galperin, A. G. Ivanov-Smolensky and many others). These investigations showed quite clearly that, contrary to the widely held view, the action of bromide consists not in a decrease of excitability, or in a decline of the excitatory process, but

* M. K. Petrova often successfully applied calcium bromide as well.

in intensification of the inhibitory process, and, above all, of different kinds of internal or active inhibition. By intensifying the concentration of the latter, bromide secondarily—owing to phenomena of positive induction—creates favourable conditions for the strengthening and, simultaneously, concentration of the excitatory process, thus establishing in the cortex proper dynamic correlations between nervous excitation and inhibition.

It was further proved that if the bromide fails to produce a positive effect, this does not always testify to the insufficiency of the dose and to the necessity of increasing it; on the contrary, in many cases the best therapeutic results can be obtained by decreasing the doses of bromide. The practice of treating experimental neuroses (in previously healthy and in castrated dogs) showed that, depending on the properties of one or another nervous system, the optimal doses of bromide vary from one or two mg. to several grammes (I. P. Pavlov, M. K. Petrova).

Chronic bromization of animals belonging to the strong and weak types revealed that in representatives of the weak type phenomena of bromism and general intoxication appeared much earlier than in representatives of the strong type (V. V. Rickman). This was manifested even more strikingly during treatment of experimental neuroses, on the one hand, in strong, equilibrated dogs, and on the other hand, in weak dogs, or those which had weakened as a result of castration (M. K. Petrova).

It followed from this that proper dosage of bromide should be based on the characteristics of the type of the animal's higher nervous activity and that the doses should conform strictly to the types of nervous system (single doses of sodium bromide administered to representatives of the strong type usually amounted to 2.0-3.0, sometimes, however, reaching even 5.0 and over; fcr

representatives of the weak type the dose varied from 0.001-0.005 to several decigrammes, more often amounting to 0.3-0.5). "The weaker the type of nervous system and the given nervous state, the smaller the dose of bromide."*

According to the recently published (1948) interesting work of M. F. Vassiliev, the bromide content in the blood of dogs belonging to different variations of the strong nervous types ranges from 0.27 to 46 mg.%, and of dogs belonging to the weak type—from 0.12 to 0.29 mg.%.

When applied over a long period bromide tends to accumulate in the organism. Its content in the blood considerably increases. Upon discontinuance of the doses it is at first rapidly excreted and then the excretion slows down and may last for many weeks (M. A. Ussievich and L. M. Georgievskaya). The effect of the action of bromide upon the dog's higher nervous activity depends not on the daily injected amount of bromide, but on the level of its general accumulation in the animal's organism. The method of impregnation with bromides (an abrupt administration of large doses of bromides or their gradual augmentation beginning with minimum doses) determines the shape and values of the cumulation curve (M. L. Petrunkin and V. V. Stroganov).

Whereas optimal doses of bromide rehabilitate the inhibitory process and intensify it, excessive doses, on the contrary, weaken the processes of active internal inhibition and lead to phenomena of deconcentration and disinhibition (M. K. Petrova, S. I. Galperin, F. P. Mayorov, V. V. Yakovleva, O. S. Rosenthal, O. P. Yaroslavtseva and others).

With the proper consideration of the above-mentioned indications and corrections relating to the application of

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 662.

bromide under collisions, breakdowns, and experimental neuroses caused by them, particularly in castrated animals, bromide, especially in combination with rest, proved in the Pavlov laboratories one of the most effective therapeutic remedies for experimental disturbances of the higher nervous activity.

However, in very severe cases, especially in cases of lasting and persistent local disturbances (connected with "isolated pathological points") neither bromide nor rest produced favourable results, and this necessitated a search for new therapeutic means.

Already the works of I. V. Zavadsky (1908) and P. M. Nikiforovsky (1910) showed that caffeine increased the excitability of the cortex, intensified the excitatory process and led to the disinhibition of differentiations. Much later (1925) it was also proved that phasic states could be eliminated for a certain time with the help of caffeine (N. V. Zimkin).

Subsequently a more detailed and thorough investigation of the action of different doses of caffeine led to the conclusion that caffeine, while increasing and accelerating the excitatory process, more or less rapidly (depending on the strength of the cortical cells and the size of the dose) exhausts and weakens the reactivity and develops phenomena of transmarginal inhibition (especially in weak and aged dogs). However, it proved possible to establish optimal doses (0.03-0.5 per dose), which increased the excitatory process, without producing any obvious symptom of its exhaustion. It was also observed that this optimal intensification of the excitatory process contributed, through the mechanism of negative induction, to the strengthening of differentiations (i.e., the processes of internal inhibition). This gave rise to the assumption that caffeine acts on the excitatory process in the same way as bromide acts on inhibition (A. M. Pav-

lova, M. K. Petrova, S. V. Klestchov, L. O. Seewald and others).

Taking into account the action of both bromide and caffeine, M. K. Petrova suggested trying their combined application in the case of an extremely persistent local neurosis. "At last," Pavlov wrote, "a favourable outlet appeared thanks to the good fortune of one of my most valuable co-workers of long standing—Dr. M. K. Petrova. Formerly Dr. Petrova worked as a therapist and later was enticed into the conditioned reflex field. For many years now she has devoted herself entirely to this work. In this connection I had an interesting experience. I must say that, although I began my professorship as a pharmacologist, I have always had a strong prejudice against introducing several substances at one time into the organism.... However, the therapist, being generally accustomed to combinations, insisted on a trial and proved to be right. The result was really extraordinary. When the dog in question was given a mixture of bromide and caffeine the tenacious neurosis disappeared at once, without leaving a trace."*

Later M. K. Petrova successfully applied combinations of bromide and caffeine in the treatment of a number of general and local disturbances of the higher nervous activity in dogs. On the basis of their experimental investigations L. O. Seewald and S. V. Klestchov also positively appraised this combination. However, depending on the type of nervous system, age, and the animal's general state, the doses had to be considerably varied (caffeine—from 0.001-0.002 to 0.1-0.2 and bromide from 0.5-0.75 to 1.0-2.0 per dose).

Characterizing the basic features of this method of treatment, Pavlov wrote: "It can be granted that, in

* I. P. Pavlov, *Experimental Pathology of the Higher Nervous Activity*, State Biological and Medical Publishing House, 1935, pp. 26-27.

most cases, diseases of the nervous system consist in disturbance of the correct interrelations between the excitatory and inhibitory processes, as it appears when applying our noxious methods. Now, if we have, so to say, two levers in the form of pharmaceutical remedies, two communicators towards the two chief instruments, namely, the processes of the nervous activity, then by putting into action and correspondingly changing the force of one or another lever we have a chance of restoring the disturbed processes to their former place, to their correct interrelations."*

In some cases M. K. Petrova obtained an increase of the conditioned reflexes by the administration of calcium chloride to neurotized dogs; in this connection she was successful in applying a combination of bromide, calcium chloride and caffeine. However, a long study of the action of calcium chloride on the course of experimental neuroses revealed also its substantial defects. Calcium chloride proved to have a considerably greater inhibitory, as well as excitatory, effect on the cortex than bromide. It was also found much more difficult to restore the nervous balance with its help than with the help of bromides. On application of excessive doses (exceeding the optimal doses, which are not always easily found), the conditioned reflex activity diminishes owing to overstrain of the cortical processes; in M. K. Petrova's words, "there develops a profound hypnotic state with all the phases peculiar to it."

Proceeding from the concept of L. A. Orbeli concerning the adaptive-trophic role of the sympathetic nervous system, with regard to the regulation of the functional state of the tissues, M. K. Petrova administered products of acid hydrolysis of fibrin (sympathomimetin —according to I. P. Chukichev) to a number of neu-

* *Ibid.*, p. 27.

rotized, castrated or aged dogs. As a result of observations carried out over a long period on six experimental neurotics, she came to the conclusion that products of acid hydrolysis of fibrin "greatly intensified in all six animals without exception the functional properties of their cortical cells. An obvious recovery of the disturbed nervous equilibrium was observed in all the dogs but in different degrees, depending on their types, age and exhaustion of their cortical cells. Better and more durable results were obtained in strong, equilibrated dogs.... The action of sympathomimetin proved to be weaker in aged dogs and in those greatly enfeebled by the difficult experimental work.... However, the wholesome effect of this preparation clearly manifested itself even in these dogs."* It produced a favourable effect also in cases of experimental phobias and dystrophic skin disturbances. Y. P. Frolov and V. V. Stroganov have also positively appraised the therapeutic action of sympathomimetin on the disturbance of the higher nervous activity in animals. All the above-mentioned experimental facts call for further investigation along these lines in order to get a final and correct opinion of sympathomimetin without overestimating or underestimating it.

The experimental investigation of the action of phenamine on the conditioned reflex activity of animals conducted in our laboratory showed that optimal doses of phenamine, while intensifying the excitatory process, at the same time stimulate the concentration of processes of internal, active inhibition (V. K. Faddeyeva).

Basing herself on Pavlov's concept of protective inhibition, which he connected with transmarginal inhibition, on the one hand and, with sleep, on the other, M. K. Petrova wrote: "Proceeding from the observations carried

* Collected Papers of the I. P. Pavlov Physiological Laboratories, Vol. XII, 1945, p. 223.

out in Pavlov's psychiatric clinic directed by Professor A. G. Ivanov-Smolensky, we began after Pavlov's death to investigate the action of veronal narcotic sleep on the higher nervous activity of typologically different neurotics—dogs of different ages."*

The sleep lasted from six to thirteen days, but more often it did not exceed six days; sometimes it occurred in one and the same animal twice or three times at intervals of two or three weeks. Veronal was administered twice a day—in the morning and in the evening—at the rate of 1.0-2.0 per dose. However, in one aged dog with a greatly weakened nervous system the dose of 0.5 administered only once a day proved sufficient to obtain deep and complete sleep lasting for six days. In all cases the application of sleep therapy contributed to the recovery of the dog's nervous activity. Narcotic sleep "proved of great benefit to all the dogs without exception, irrespective of the type of nervous system, age and degree of exhaustion" (M. K. Petrova). Particularly effective was its action on trophic skin disorders: ulcers, eczemas, papillomas and loss of hair. All dogs subjected to narcotic sleep became considerably less susceptible to various nervous traumas than they were in the preceding years.

Together with the experimental application of prolonged narcotic sleep, M. K. Petrova in a number of other experiments used weak, monotonous stimuli, continuous extinction, a slowly blinking blue light and a weak mechanical skin stimulation; in this way she obtained in dogs a deep sleep (hypnotic sleep, according to her terminology), which she also widely used for therapeutic purposes, sometimes combining it with small doses of

* Proceedings of the Session Dedicated to the 10th Anniversary of I. P. Pavlov's Death. U.S.S.R. Academy of Medical Sciences, 1948, p. 150.

sympathomimetin (for example, in cases of experimental phobias). Proceeding from the fact that in severe pathological nervous states, owing to the exhaustion of the cortical cells, the dogs exhibit phenomena of transmarginal, protective inhibition, which easily pass over into sleep, M. K. Petrova allowed the dogs an additional two and a half to three hours' (hypnotic) sleep daily for periods varying from three weeks to three months, and thus obtained full recovery of the higher nervous activity in neurotized dogs.

D. A. Kamensky allowed his experimental dog 20-30 minutes' natural sleep either directly before the experiment or in the course of it, and this had a wholesome effect on the cortical dynamics of the animal and on the efficiency of its cerebral cortex.

The differential indications of diverse therapeutic methods applied in the treatment of experimental neuroses and related pathological states, are still to be specified for the purpose of their proper utilization; in other words, it must be established in which cases these or other methods are most effective. To a degree this will be, apparently, the essence of further work in this field. But at present we can only state that, under functional disturbance of the higher nervous activity in animals, particularly beneficial results were obtained chiefly a) by the administration of different bromides ($NaBr$, $CaBr_2$, KBr) depending on the typological characteristics; b) by the combination of bromide and caffeine; c) by stimulating protective inhibition (protracted narcotic sleep, hypnotic sleep and, finally, prolonged natural sleep).

As already mentioned, narcotic sleep therapy was successfully applied during the Great Patriotic War by E. A. Asratyan in cases of experimental traumas of the spinal cord and brain in dogs. Like the investigations of M. K. Petrova, this work, too, was based on Pavlov's concept of protective-curative inhibition.

In describing the experimental investigations conducted by our laboratory in the field of the patho-physiology of neurotoxicoses we pointed out that sharply expressed phenomena of protective transmarginal inhibition usually emerged at the height of intoxication and often during the prolonged after-effects caused by it. This impelled us to try artificially to strengthen this inhibition for therapeutic purposes. The first attempt in this direction was made by us in cases of mescaline intoxication in guinea pigs, where first (in the acute period) phenomena of diffused inhibition were clearly observed and later, over a period of several months, chronic changes of the higher nervous activity, mainly having the character of phasic states. A protracted narcotic sleep (lasting three days) was produced with the help of amytal sodium (experiments of L. E. Khozak). In this way it proved possible to obtain complete and durable recovery of the conditioned reflex activity in most of the experimental animals during the next four months. In some animals recovery was attained only after two courses of protracted narcotic sleep. Favourable results were also obtained in a number of white rats intoxicated with tetraethyllead; here too a three days' amytal sodium sleep was applied (experiments of L. S. Gorsheleva). We have already mentioned that pasteurellosis, an infection which in rats is usually of a persistent and lethal character, is accompanied by the development of slowly progressing disturbance in cortical activity; in the end, the disturbance leads to complete disappearance of the conditioned connections, which first pass through a number of phasic states. By means of a narcotic (amytal) three days' sleep, and sometimes repeating it twice or three times, it proved possible in many cases to obtain a more or less prolonged, but, as yet, temporary rehabilitation of the conditioned reflex activity; in several cases even complete

rehabilitation of this activity and full recovery of the animals were attained (experiments of A. Y. Izergina and V. K. Faddeyeva).

Recently positive results were obtained in our laboratory by application of protracted amytal sleep in treating toxicoses caused in animals by staphylococcal and streptococcal toxins (Gorsheleva, Kotliarevsky) and in certain allergic states (Khozak).

However, whereas the favourable effect of protracted narcotic sleep on the work of the higher parts of the central nervous system is beyond doubt, its influence on the course of somatic diseases has not yet been sufficiently clarified and requires further investigation.

Thus we see that, although our attempt to use protracted narcotic sleep in the treatment of experimental neurotoxicoses and infectious diseases in animals still does not give ground for final conclusions, its results are encouraging at least, and open up certain prospects for experimental therapy. In this attempt Pavlov's idea of artificially stimulating and intensifying the phenomena of protective inhibition for therapeutic purposes finds further practical realization.

11

THE CONNECTION BETWEEN EXPERIMENTAL PATHOLOGY OF THE HIGHER NERVOUS ACTIVITY AND EXPERIMENTAL THERAPY

We have seen that the theory of pathological states of the higher nervous activity resulting from noxious functional influences, which developed in the Pavlov school in the early twenties of this century, steadily gained in scope and, constantly setting itself new tasks always maintained close contact with the problems of

experimental therapy. There was nothing fortuitous in this, since the whole of Pavlov's scientific activity was permeated with the same noble idea.

As early as 1900, Pavlov, speaking of the successes achieved in the physiology of the animal organism (in the field of vagotomy), stated: "Our command over the animal organism is steadily growing. After a period of analytical work we have without the slightest doubt entered into a period of synthetical work.... The synthesis ... is effected by physiological investigations of two kinds. On the one hand, the activity of the organism as a whole and of its parts in strictly normal conditions and in connection with these conditions is being eagerly studied.... On the other hand, problems are being raised and solved, which aim at the neutralization and elimination of the damage caused to the organism by severe disturbances of one kind or another."*

Thirty-five years later, in one of his last works devoted to experimental pathology of the higher nervous activity, Pavlov made the following statement (1935): "The power of our knowledge over the nervous system will, of course, appear to much greater advantage if we learn not only to injure the nervous system, but also to restore it at will. It will then have been really proved that we have mastered the processes and are controlling them. Indeed, this is so. In many cases we are not only causing disease, but are eliminating it with great exactitude, one might say, to order."**

What a remarkable example of irreproachable and strict consistency this is! What steady and invariable adherence during thirty-five years of scientific activity to one and the same lofty idea, to one and the same high principle!

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* I. P. Pavlov, *Complete Works*, Vol. I, U.S.S.R. Academy of Sciences, 1940, pp. 362-63.

** I. P. Pavlov, *Twenty Years of Objective Study*, p. 690.

Pavlov concluded the above-mentioned article with the following words: "Thus you see that in the field of pathology our method, the method of objective treatment of the highest phenomena of the nervous activity in animals is fully justified; and the more we use it, the more it is justified. At present we are making, as it seems to me, lawful attempts to apply this same method also to the human higher nervous activity, usually referred to as psychical activity."*

I. P. Pavlov, *Twenty Years of Objective Study*, pp. 699-700.

ESSAY III

INVESTIGATIONS IN THE SPHERE OF THE CLINICAL PATHO-PHYSIOLOGY OF THE HIGHER NERVOUS ACTIVITY

1

THE BASIC STAGES IN PAVLOV'S APPROXIMATION TO THE CLINIC OF NEUROPSYCHIC DISEASES

We know that the problem of experimental psycho-pathology based on a study of animals had long attracted Pavlov's attention and was raised by him already in his first work on the theory of higher nervous activity, which was just taking shape (1903).

But the problems of human psycho-pathology and at the same time of major and minor psychiatry* were tackled by Pavlov much later, although, according to him, they had attracted his interest long before.

In 1919 he published his work "How Psychiatry Helps Us to Understand the Physiology of the Cerebral Hemispheres,"—a paper read by him before the Petrograd Society of Psychiatry in the same year.

In this work he wrote the following: "My earlier researches on the circulation of the blood and on digestion led me to the firm conviction that the physiological mode of thinking may derive great help from the study of clinical cases, i.e., from the countless number of diverse pathological variations and combinations of the functions of the human organism. For this reason, during many years of work on the physiology of the cerebral

* As is known, minor psychiatry mainly consists of the theory of general neuroses.

hemispheres I often thought of making use of the world of psychiatric phenomena as an analytical auxiliary to this physiological study.... In the summer of 1918 I had at last the opportunity to study a number of cases of insanity. And, as it seems to me, my former hopes have not been in vain. In some instances I saw excellent demonstrations of points more or less explained in physiology; in others, new aspects of the work of the brain were brought to light, new questions and new and unusual problems for laboratory investigation arose."*

Later we shall dwell in greater detail on this extremely interesting paper which was the result of Pavlov's visits to one of the Petrograd psychiatric hospitals; for the present we shall but stress that already at the time when he made his first approach to the domain of human neuropsychic diseases, Pavlov regarded it first of all as a source of auxiliary material for the study of the physiology of the higher parts of the central nervous system. This was expressed with particular force in the concluding words of the above-mentioned paper: "One can hardly doubt, I think, that the physiological analysis of the above cases suggests many new problems for the laboratory investigation of the physiology of the brain."

As is known, the theory of experimental neuroses began to develop in the Pavlov laboratories in the early twenties; in this connection Pavlov's eager questioning turned more and more frequently to the problems of psycho-pathology, and this made him resume his visits to the psychiatric hospital.

In the autumn of 1931, in accordance with his wish, two special clinics were opened in his laboratories—a psychiatric clinic and a neurological one (in point of fact the latter was a clinic for neuroses); each was

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 349-50.

provided with a laboratory for experimental investigation of the higher nervous activity of the patients.

As a result of his regular (weekly) visits to these clinics and his systematic investigations of the various forms of neuropsychic diseases (general neuroses and psychoses), Pavlov, on the one hand, obtained new material for further experimental research, modelling certain disturbances of the human cerebral activity on his experiments on animals; on the other hand, basing himself on the rich experimental material of these laboratories and taking into account the specific properties of the work of the human brain, he aimed at a pathophysiological understanding and explanation of neuropsychic disturbances in man.

When acquainting himself with anamnestic data, Pavlov paid particular attention to the previous life experiences of the patient; the conditions under which he had been reared and educated; the peculiarities of his social and family relations, his trade or profession and his social adaptability; the somatic diseases suffered before, the psychogenic shocks and mental traumas he had experienced; features of the premorbid personality and the peculiarities of the type of the patient's higher nervous activity (mostly under neuroses).

It was precisely here, in the clinic of neuropsychic diseases and in the course of studying various pathological disturbances of the human higher nervous activity, that Pavlov with particular force stressed his idea of "an extremely important addition" in the mechanism of the human cerebral activity compared with the nervous activity of animals, the idea which he had first expressed as far back as 1927 in his final lecture on the work of the cerebral hemispheres.* According to Pavlov,

* In this lecture Pavlov spoke of "the grandiose signalling medium--speech."

"this addition relates to the speech function which signifies a new principle in the activity of the cerebral hemispheres. If our sensations and notions caused by the surrounding world are for us the first signals of reality, concrete signals, then speech, and especially and primarily the kinesthetic stimuli which proceed from the speech organs to the cortex, constitute a second set of signals, the signals of signals. They represent an abstraction from reality and make possible generalizations which constitute ... *specially human, higher mentality*, creating first an empiricism general to all men, and then, in the end, science, the instrument of the higher orientation of man in the surrounding world and in himself."*

Thus, the theory of the first and second signalling systems of the human cerebral cortex actually originated in the clinic. Later we shall more than once come back to this theory; but here we shall only touch upon another, fuller description of these systems given by Pavlov much later—in 1935.

"When the developing animal world reached the stage of man, an extremely important addition was made to the mechanisms of the nervous activity. In the animal, reality is signalized almost exclusively by stimulations and by the traces they leave in the cerebral hemispheres, which come directly to the special cells of the visual, auditory or other receptors of the organism. This is what we, too, possess as impressions, sensations and ideas of the world around us, both the natural and the social—with the exception of the words heard or seen. This is the first system of signals of reality common to man and animals. But speech constitutes a second signalling system which is peculiarly ours, being the signal of the

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 615-16.

first signals. On the one hand, numerous speech stimulations have removed us from reality, and we must always remember this in order not to distort our attitude to reality. On the other hand, it is precisely speech which has made us human, a subject on which I need not dwell in detail here. However, it cannot be doubted that the fundamental laws governing the activity of the first signalling system must also govern that of the second, because it, too, is activity of the same nervous tissue."*

Investigating in his clinics various forms of neurotic and psychotic disturbances, Pavlov invariably strove to disclose and understand the pathogenic nervous mechanisms of these disturbances in order to detect and reveal the pathological changes in the higher nervous processes which underlie morbid psychic disorders, morbid derangement in the behaviour of patients and in their utterances.

In other words, he strove "to superimpose a psychopathological pattern on the patho-physiological canvas" (somewhat paraphrasing his own words concerning the interrelations between psychology and physiology).

At the same time, however, as we shall see later, he was greatly interested in problems relating to improvement and scientifically justified reorganization of the maintenance, care and regimen of the mentally ill; he was interested even to a still greater degree in the problem of elaborating new, pathogenically grounded, methods of treatment.

* *Ibid.*, p. 722.

2

THE BASIC PRINCIPLES OF PAVLOV'S WORK IN THE SPHERE OF CLINICAL PATHO-PHYSIOLOGY OF THE HIGHER NERVOUS ACTIVITY

In the very first years of his work in the clinics, Pavlov made an attempt to systematize the disturbances he observed there, on the basis of their localization in the different parts and functional systems of the brain.

The first system establishing complex correlations between the organism and the external environment, where certain initial disturbances of nervous activity may arise, is the system of subcortical regions adjacent to the cerebral hemispheres; the activity of these regions manifests itself in highly complex unconditioned reflexes (or instincts). Pathological derangement of these functions tells first of all on the emotional, affective activity closely connected with them, but in which, naturally, the cerebral cortex always participates; hence, derangement of this activity may in some cases develop mainly in its subcortical foundation, and in other cases—mainly in the cortex (i.e., in a "somatogenic" or "psychogenic" way).

Next comes the first signalling system—the vehicle of imaginative, objective, concrete, emotional thought, acting under the direct (asymbolic, speechless) influence of the external world and the organism's internal medium. Pathological disturbance of this system may be caused by direct external emotiogenic or affectogenic influences, but it may also be originated by the higher or lower systems. In the latter case this disturbance may be evoked by the pathological condition of an internal organ or entire system of organs, which, for a certain period or constantly, send out prolonged, unusual or excessively strong pathological stimuli to the respective cortical cells of the first signalling system.

Finally, the last and at the same time highest system is the second signalling system with its "specially human, higher mentality," i.e., verbal thought inherent in which is abstraction from reality and the forming of generalizations; according to Pavlov, "this is the highest regulator of human behaviour."

The pathological disturbance observed here may arise as a result of external influences, as well as of influences proceeding from the first two systems.

It is absolutely impossible to assume any isolated lesion of one of these systems. A separate system can only be regarded as the initial source of the disturbance or the seat of the predominant disturbance; but it should be borne in mind that pathological disturbance usually affects the functional correlations between all three systems, that the dynamic changes spread to all these functional systems in a lesser or greater degree.

Nor should it be forgotten that in these systems disturbance may develop in a neurogenic (reflex) way, originating in the sense organs and in the receptor endings of the skin or of the internal organs (i.e., exteroceptively, interoceptively and proprioceptively), as well as in a neuro-humoral, "automatic," way, through the blood and cerebrospinal fluid and, finally, in a neurotrophic way, when the trophic influences are dissociated.

Pavlov said: "When we turn to human beings, we, naturally, must take into consideration both the different causes and conditions which obviously must lead to varying degrees and to a different course even of one and the same basic pathological disturbance. Certainly, in addition to congenital conditions there are, inevitably, cases when the nervous system is unsteady and fragile as a result of misfortune in life—traumatic lesions, infections, intoxications and severe shock."*

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 644-45.

As we shall see later, phenomena of diffused inhibition arising at one of the higher levels, in an evolutionarily higher functional system, provided the inhibition does not extend to the subordinated lower systems, result in the elimination of the regulating influences upon them; they lead to the liberation, disinhibition and positive induction of functions in the subordinated systems and, at the same time, as frequently happens in such cases, to their dissociation.

In the light of Pavlov's fundamental principles the following most urgent research problems are now confronting the patho-physiology of the human higher nervous activity:

1) Pathological changes in the force, equilibrium and mobility of the excitatory and inhibitory processes; morbid peculiarities of nervous excitation, as well as of the processes of internal, active, or, in the broad sense, conditioned inhibition and of passive or unconditioned inhibition (external inhibition, negative induction and transmarginal protective inhibition); deviations from normal sleep inhibition; derangement of the course and interaction of cortical processes.

2) Pathological changes of functional interrelations between cortical and subcortical activity: pathological irradiation of the excitatory and inhibitory processes, descending from the cortex to the subcortex and ascending from the subcortex to the cortex; abnormal relations of induction, such as induced inhibition of the cortex under pathological excitation in the subcortical regions, inhibition of the subcortical regions under pathological excitation in the cortex, disinhibition and dissociation of subcortical functions under pathological inhibition of the cortex, etc.

3) Pathological changes in the interaction of the dynamic correlations between the first and second signalling systems of the cortex, expressed now in the predomi-

nance of one over the other, now in various dissociations of their joint activity; in some cases these dissociations assume a more general, extended form, in others—a particular, relatively local form.

Special importance must be attached to the investigation of such frequent and usual disturbance observed in neuroses as sleep disorder. One of the most typical disorders of this kind, often met with in neurotics with a sharply expressed inertness of the cortical processes, is the difficulty with which they fall asleep and wake up; this reflects pathological inertness of sleep inhibition, which slowly increases and equally slowly diminishes. In addition, there develops inertness of the excitatory process which is also responsible for the impeded transition from wakefulness to sleep.*

Studying various mental disorders in the clinic, Pavlov regarded symptoms, syndromes and disease as manifestations of qualitatively different general or relatively local disturbance of the higher nervous activity, which, in one way or another, is usually connected also with somatic disturbance; at the same time Pavlov always took into account the peculiarities of the type of nervous system of the patient. However, he regarded this as a highly complicated matter, and his statements on the type of human higher nervous activity were notable for their extreme caution.

"Since normally our general behaviour, and that of higher animals (we imply here healthy organisms) are directed by the higher part of the central nervous system—by the cerebral hemispheres and the adjacent subcortex, the study of this higher nervous activity under normal conditions by the method of conditioned reflexes

* A. G. Ivanov-Smolensky, *Fundamental Problems of the Patho-Physiology of the Higher Nervous Activity*, 1933, pp. 415-16 and 459.

must lead to knowledge of the actual types of nervous activity and the basic models of behaviour of human beings and higher animals.... Before proceeding to our factual material we must touch on one very substantial and so far almost insurmountable difficulty connected with defining the type of nervous activity. The behaviour of a human being and of an animal is determined not only by the congenital properties of the nervous system, but also by the influences constantly exerted on the organism throughout its individual existence, i.e., it depends on constant education or training in the broadest sense of these words. This is due to the fact that along with the above-mentioned properties of the nervous system, another very important property incessantly manifests itself—its high plasticity. Consequently, since this is a question of the natural type of nervous system, all the influences to which the given organism has been exposed right from the day of its birth must be taken into consideration."*

If defining the type of nervous system in animals does not always present an easy task, in respect to man it becomes much more complicated and its solution entails extreme difficulty.

First of all in human society the significance of the strength of the nervous system recedes to a considerable degree into the background, giving way to the significance of the social value of the human personality; these two concepts—of nervous strength and social value—do not always coincide and are not always in consonance.

Hence, while not denying the positive significance of a strong and, especially, equilibrated nervous system for the human personality, we must never lose sight of the decisive significance of its social value, and this, of

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 653.

course, fully holds good also for appraisal of representatives of the weak types of higher nervous activity.

Moreover, another, no less important and also highly complicated question arises: what are the criteria for the strength of the human nervous system? Here, apparently, of prime importance is the ability of the nervous system to endure unfavourable external conditions and severe life situations and at the same time to find correct solutions for the difficult tasks and the right way out of the complicated situations without experiencing nervous breakdowns. But even when appraising the correctness of the solution of a certain life problem by a human being it is impossible to ignore the social factors, not to give a social appraisal of the way out found by him.

It should be also borne in mind that difficult tasks lead to breakdowns not only in representatives of the weak types of the higher nervous activity, but, depending on the nature of the task, also in representatives of the strong types; consequently, this requires due consideration of all the peculiarities of the given difficult task.

Further, it is also necessary to give due measure to the peculiarities of the previous life experiences—formerly endured nervous breakdowns and the prolonged or temporary weakening of the nervous system, particularly that caused by repeated nervous traumas (of a functional or crude, mechanical nature), as well as by various somatic and nervous diseases.

However, past experience must be also considered from the reverse aspect, namely, from the aspect of developing the ability to overcome difficulties and of cultivating social principles and habits of discipline which help to overcome the difficulties.

Thus, the strength of the nervous system in man is greatly overshadowed and, at the same time, greatly

dependent on the peculiarities of the previous experience moulded by the social environment. All that has been said above applies in full measure also to such indications of the strength of nervous system as efficiency, as well as the steadiness of the cultivated social-ethical inhibitors (i.e., the ability to suppress emotional and affective reactions not in keeping with the given situation), which we usually term self-restraint and self-possession. But here we already enter the sphere of proper correlations between the excitatory and inhibitory processes and of their equilibration—which is much more accessible to the study of human higher nervous activity than the strength of the nervous system.

The features of heightened excitability, or, on the contrary, of heightened inhibitability, are sharply expressed in human behaviour, although, of course, here, too, one cannot ignore the compensatory, obliterative influences of past experience, and the significance of social factors.

The typological properties of the mobility of nervous processes are revealed with greater difficulty; they are most prominent in cases when quick transition from one kind of activity to another is required. It would be absolutely erroneous to think that the difficulty of adaptation to new conditions is due solely to insufficient mobility of the cortical processes. Here too, as in all previous cases, the peculiarities of the life experience must be taken into consideration, namely, the acquired ability of adaptation to changes in the mode of life and surroundings, or, on the contrary, lack of experience in this respect.

Also of great importance is the nature of interrelations between the excitatory and inhibitory processes: under heightened inhibitability, the inhibiting action of the novelty, caused by the transition to new and unusual conditions, impedes quick and adequate adaptation to these conditions.

Finally, the peculiarities of the change itself, of the new conditions, must be taken into account: if they entail the formation of many qualitatively new habits and unusual views, without any essential change of old habits and practices, they will, undoubtedly, prove difficult for representatives of the inhibitable type.

If such new conditions, in contrast to the old, necessitate the formation of a number of new inhibitory habits, and in general if they call for a greater strain of the internal, active inhibitors (overstraining, for instance, the self-control and self-possession), then adaptation to these conditions will be particularly difficult for representatives of the excitable type. And finally, if the changed conditions are connected with an abrupt change of the habitual mode of life and behaviour, they will reveal the peculiarities of the mobility of nervous processes to the greatest possible extent, in some cases disclosing the positive qualities and in others—the inertness of these processes.

In a word, it should be borne in mind that adaptation to new conditions depends not only on the nature of the adaptive mechanisms inherent in the given nervous system, but also on the peculiarities of the new situation compared with the previous one.

Moreover, in such cases the process of adaptation must be regarded, in Pavlov's words, "on the one hand, as the influence exerted by reality on the organism, and on the other hand, as the action of the organism on the outer world."*

What we want to say is that the adaptation of various types of the human higher nervous activity to new conditions is not always of a passive nature (which is mostly peculiar to the inhibitory type); these conditions

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 432.

are also actively adapted by human beings to their own needs and in accordance with their previous experiences and their social views.

As we shall see later, Pavlov introduced into the study of the types of human nervous activity two new criteria for defining the types: on the one hand, the peculiarities of the interrelations between cortical and subcortical activity, and on the other, the peculiarities of interaction of the first and second signalling systems.

3

PAVLOV'S VIEWS ON THE TYPES OF HUMAN HIGHER NERVOUS ACTIVITY

After these preliminary remarks we shall pass to Pavlov's views on the types of human higher nervous activity.

We recall once more that the study of the types of higher nervous activity, especially in man, was considered by Pavlov as a difficult, and at times even insoluble task. We recall also, that, according to him, one of the most important properties of the nervous system is its inherent "high plasticity," and, consequently, when defining the type of nervous activity, it is necessary to take into account all the influences to which the given individual has been exposed.

Comparing Hippocrate's grouping of temperaments with various types of the higher nervous activity as applied to man, Pavlov stated the following (1927): "The melancholic temperament is evidently an inhibitory type of nervous system. To the melancholic every event in life becomes an inhibitory agent, since he believes in nothing, hopes for nothing, sees only the dark side in everything, and expects from everything only grievances. The choleric type is pugnacious, passionate, easily and

quickly irritated."* As we already know, Pavlov most readily applied the term "impetuous" to the excitable type.

Characterizing the central, medium, equilibrated types—"the healthy, stable and really viable nervous types," he said: "The phlegmatic is self-contained and quiet—a persistent and steadfast toiler in life. The sanguine is energetic and very productive, but only when his work is abundant and interesting, i.e., if there is constant stimulation. When he is without such a task, he becomes bored and slothful. . . . We ventured to speculate and consider, to go somewhat further, touching the clinics of nervous and mental diseases. . . . We believed that these clinics drew their material chiefly from the extreme, unstable human types or temperaments. . . ."**

As we have seen, the further development of the theory of types of higher nervous activity and of experimental neuroses has disclosed that even representatives of the strong equilibrated types of nervous system are not free from overstrain of the cortical processes and from nervous breakdowns with their ensuing pathological states of a more or less protracted character.

"Of course," Pavlov stated in one of his works, "even great men, however strong they may be, are subject to breakdowns, since the scale of their life activity is extraordinary and there is a limit to any strength."***

We have also seen that such pathological states develop with particular ease and take particularly severe forms on the background of vegetative-endocrine disturbances, somatic diseases and, in general, on the background of various pathological changes in the internal medium of the organism.

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 468.
** *Ibid.*, pp. 468-69.
*** *Ibid.*, p. 678.

Functioning under the most unfavourable conditions, according to Pavlov, are those nervous systems "which, in consequence of the difficulties experienced during life, possess only a small store of excitatory substance in the cortical cells, and consequently easily pass over into the inhibitory state, into its varied phases, or even remain permanently in one of these phases."*

Regarding representatives of the weak and unequilibrated type of higher nervous activity as being most susceptible to neuropsychic diseases, but not including them in the category of pathological types—looking on them as extreme variations of the normal—Pavlov rejected the theory of constitutions suggested by Kretschmer.

In 1935 he wrote: "Kretschmer's classification of nervous types, which has obtained practically universal recognition, especially among psychiatrists, must be regarded as mistaken or inadequate. Kretschmer's types have been drawn from the clinic. But are not there absolutely healthy individuals, must all humans have constantly nervous and mental diseases in embryo?"**

Regarding all the typological variations described by Kretschmer "only as a part of all the human types," Pavlov suggested that cyclothymics are closest to the excitable, impetuous type of nervous system, and schizothymics closest to the weak, inhibitable type. He said: "Since the first type lacks a proper abating and restorative process—the process of inhibition—its excitatory process often considerably exceeds the working capacity of the cortical cells, and this is responsible for the derangement of the proper succession of normal work and normal rest. . . . In the second type both processes are weak, and therefore, it cannot endure individual and social life

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 446.
** *Ibid.*, p. 676.

with the accompanying very severe crises, which mostly act on the still young, not sufficiently adjusted and hardened organism. . . . Aloofness or reticence which, according to Kretschmer, is the main feature of schizothymics from childhood, does not present anything specific; in the case of a weak nervous system it is merely a general indication of the extreme difficulty experienced in the social environment; hence the natural withdrawal from it. . . . It should be added that reticence or aloofness from society is by no means an exclusive feature of schizothymics, i.e., of weak individuals. Even strong individuals may be reserved, but for quite different reasons. Such individuals lead a strenuous but at the same time one-sided subjective life; early on they are gripped by a definite inclination, they concentrate on a single aim and are obsessed and carried away with a single idea. Other people are not only undesirable to them; they are even upset by them and distracted from the principal object of their life."*

However, along with the certain resemblance between the psychical constitutions described by Kretschmer and some of the types of higher nervous activity, there is an irreconcilable and fundamental difference between them: whereas for Kretschmer his psychical constitutions are genotypic, hereditarily determined and congenital, in Pavlov's view, the formation of the type of higher nervous activity depends on "education or training in the broadest sense of these words,"** on the properties acquired during life, on the diverse influences exerted by the external—social—environment, which to a tremendous degree restrict the significance of hereditary pre-conditions.

* *Ibid.*, pp. 677-78.
** *Ibid.*, p. 653.

It would be also absolutely wrong to identify the concept of a cyclothymic and schizothymic, on the one hand, and the concept of the excitable and inhibitable types of nervous system, on the other. The latter concept is much broader. We must stress once more that, according to Pavlov, they do not come within the category of pathological types, being but extreme variations of the normal types of higher nervous activity, although least equilibrated and adaptable and most delicate and fragile.

As mentioned above, Pavlov repeatedly stressed the significance of the "extremely important addition," which in the course of evolution has been acquired by human brain activity. Naturally, he could not but take this into consideration when discussing the problem of the types of human nervous system. He said:

"Life clearly reveals two groups of human beings: artists and thinkers. There is a striking difference between them. The first group, artists of all kinds—writers, musicians, painters, etc., perceive reality as a single whole, that is, the entire living reality without breaking it up or decomposing it. The other group, the thinkers, on the contrary, dismember it, thereby, as it were, killing it and making of it a kind of temporary skeleton; only afterwards do they gradually, as if anew, assemble its parts and try to revive it, but this, however, they are unable fully to accomplish."*

It should be borne in mind that here Pavlov speaks not of the division of all human beings into two groups, but of the fact that these two specific groups or categories are met among them.

It is not difficult to note that these categories include individuals with certain peculiarities of interrelations between the first and second signalling systems of the cerebral cortex: in one category the first signalling sys-

I. P. Pavlov, *Twenty Years of Objective Study*, p. 596.

tem predominates (in the artists), in the other (the thinkers) the second signalling system prevails. However, here, too, it is not a question of pathology, but of normal typological variations formed under certain social conditions.

"Before the appearance of the family of *homo sapiens* the contact of the animals with the surrounding world was effected solely by means of direct impressions produced by its various agents which acted on the different receptor mechanisms of the animals and were conducted to the corresponding cells of the central nervous system. They were the sole signals of external objects. In the future human beings there emerged, developed and perfected, signals of the second order, signals of these initial signals, in the shape of speech—spoken, auditory and visible. Ultimately, these new signals began to denote everything taken in by human beings directly from the outer, as well as from the inner world; they were used not only in mutual intercourse, but also in self-communion. This predominance of the new signals was conditioned, of course, by the tremendous significance of speech, although words were and remain but second signals of reality.... However, without entering deeper into this important and very broad subject, it is necessary to state that thanks to the two signalling systems, and by virtue of the long-established different modes of life, human beings in the mass have been divided into artistic, thinking and intermediate types. The last-named combines the work of both systems in the requisite degree."*

In other words, in some people the predominance of one of the basic cortical systems is sharply expressed, while in others this pronounced predominance is not observed. In essence, it is a question of individuals with

* *Ibid.*, pp. 732-33.

a distinct predominance of imaginative-emotional or abstract-verbal thinking and of individuals without such one-sided predominance, that is, people in whom both are equally developed. The correlations with the excitable, inhibitable and equilibrated types are, to a considerable degree, a matter for further research, although Pavlov studied this question too.

As we shall see later, the peculiarities of the interaction of the first and second signalling systems attracted his attention also in connection with problems of the patho-physiology of the higher nervous activity.

4

THE SIGNIFICANCE OF THE THEORY OF EXPERIMENTAL NEUROSES FOR THE CLINIC OF HUMAN GENERAL NEUROSES

In his study of human general neuroses in clinical conditions, Pavlov strove from the very outset to grasp, first of all, their underlying pathogenic nervous mechanisms; secondly, he investigated the disturbance of the neuro-dynamics peculiar to various neurotic states, the patho-physiological substratum of different neurotic phenomena, and thirdly, he endeavoured to pave the way for a pathogenically grounded therapy of these diseases.

Naturally, in this work he took as his starting point the rich and valuable experimental material supplied by his laboratories regarding overstrain of the cortical processes, nervous breakdowns and experimental neuroses as the simplest designs of the disturbance of the higher nervous activity observed in the clinic.

In 1931 he wrote: "But I am convinced that the solution, or substantial assistance to the solution, of many important problems relating to the aetiology, natural systematization, mechanism, and finally, treatment of

human neuroses is in the hands of those who experiment with animals."*

The polemic in the early thirties between Pavlov and one of the outstanding foreign psychiatrists, the psycho-analyst P. Schilder, clearly showed that Pavlov, who had embarked on a new path of studying neuroses, would experience difficulties in finding a common language with the clinicians, and that he would hardly meet with adequate understanding on their part.

Not denying that the pathological states experimentally obtained in dogs "display all the phenomena of neuroses," P. Schilder maintained that it was impossible to understand human neuroses on the basis of these facts, whereas the experimental neuroses in dogs could be easily explained with the help of psycho-analytical mechanisms.

If an astrologer of the remote past had been able to acquaint himself with present-day astronomical data, he would probably have considered them absolutely unnecessary, being quite satisfied with the habitual, easily comprehensible astrological explanations of that time.

Replying to P. Schilder, Pavlov wrote: "In the case of man it is first of all necessary to define exactly the nature of the given deviation from normal behaviour, remembering that normal behaviour in different human beings, too, is extremely varied. Then it is necessary with the help of the patient, or without his knowledge, and sometimes even overcoming his resistance, to detect in the chaos of his lifetime relations the conditions and circumstances which acted abruptly or gradually and were most probably responsible for the onset of the morbid deviation, for the emergence of the neurosis. Further, it is necessary to find out why these conditions and circum-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 575.

stances had this effect on our patient, while on other individuals they did not exert even the slightest influence. And still more, why is it that in one person they resulted in such a pathological complex, while in others they produced altogether different ones? Here I touch only upon the fundamental, so to speak, group questions, leaving aside the great variety of particular questions. But are these questions always answered in a completely satisfactory manner?

"Besides, this is only part of the whole problem, provided we really aim at a full and profound analysis. Of course, the nervous system is responsible for the deviations in our patient's behaviour. Who can doubt this now? But then it is necessary also to answer the following questions: what are the changes that have taken place in the normal processes of the patient's nervous system? How and why did they develop?

"Are not all these demands practicable? And why have not they been fulfilled?"*

Indeed, the clinic of neurosis, and P. Schilder in particular, could not provide the answer to these questions, since up to that time the clinical theory of neuroses had been formed without the participation of the physiology and patho-physiology of the higher parts of the central nervous system.

"In the case of man," Pavlov continued, "with the complexity of his conditions of life and diversity of his reactions to them highly complicated questions always arise, of importance both for the purpose of analysis and treatment: which conditions proved to be unduly strenuous for the given nervous system? Where and when did the demands of activity come into unendurable collision with the demands of its delay?"**

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 531.

** *Ibid.*, p. 533.

While observing neuroses, Pavlov raised a number of diverse problems. In particular, he was interested in the questions, whether neuroses always develop only under nervous disequilibrium or whether they may also arise in representatives of the equilibrated types.

Both laboratory experiments and clinical observations led him to a positive answer to the second question: under extremely severe and hard conditions of the external, as well as internal medium (various somatic diseases) neuroses may develop also in representatives of the strong, equilibrated type of nervous system; but naturally they are observed more frequently in representatives of the weak and unequilibrated types.

Pavlov was also interested in disclosing the basic conditions within the organism which determine the normal activity of the central nervous system and to a considerable degree its stability and resistance to external difficulties, to harmful situations causing overstrain of the cortical processes and leading to nervous breakdown. In other words, he strove to reveal the basic conditions in the internal medium of the organism which prevent heightened susceptibility of the brain to functional nervous traumas (i.e., to psychical traumatization).

In close connection with this there arose another question: to what extent does the initial disequilibrium of the nervous system present a primary phenomenon, i.e., stipulated by the external conditions of its ontogenic, individual development, by its acquired and inborn properties, and to what extent does it bear a secondary character, i.e., to what degree does it depend on the peculiarities of the activity of the other physiological systems of the organism, apart from the nervous system?

Thus Pavlov devoted constant attention not only to the external conditions responsible for each particular case of neurosis, but also to the peculiarities of the patient's somatic state. The very close connection of the

higher nervous activity with the general somato-physiological activity of the organism was always regarded by him as the influence of other physiological systems on the activity of the nervous system and, even to a still greater degree, as the diverse influence of the latter on the internal medium of the organism. Here, too, he did not abandon the idea of continuous interaction of the nervous and the somatic, the idea of nervism.

In one of the last articles (1935) concluding his *Twenty Years of Objective Study of the Higher Nervous Activity (Behaviour) in Animals,* Pavlov stated: "There is no doubt, of course, that the fundamental laws of nervous activity must be identical in man and in animals, both in normal and in pathological states. Consequently, identical physiological factors also underlie all our complex manifestations and emotions. This particularly arrests the attention of every observant researcher in cases of animal neuroses which are comparable to human neuroses. Hence, we must draw the highly instructive conclusion that for a truly scientific understanding of our neuropathological symptoms and for successful struggle against them it is necessary to do away with the demarcation between the psychical and the somatic, so deeply ingrained in us. We must always proceed from physiological concepts both in respect to the morbific agents and the reactions to them with all their consequences. i.e., to shift the entire psychogeny and symptomatology to a physiological basis."*

The question of the connection between disequilibrium of the higher nervous activity and the work of other physiological systems was elucidated not only by means of clinical observations, but to a considerable degree also by experiments on animals (a substantial part of these experimental data, however, was obtained

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* I. P. Pavlov, *Twenty-Years of Objective Study,* pp. 738-39.

after Pavlov's death in the laboratories directed by his disciples).

Let us recall, for instance, the experiments connected with removal of the thyroid gland or with castrated dogs, which revealed the tremendous influence of the endocrine-vegetative system on the activity of the higher parts of the central nervous apparatus. The injury experimentally caused to this system, as we remember, produced complete derangement of the higher nervous activity, in some cases immediately, in others—somewhat later.

As a result of various somatic diseases, especially of an infectious origin, there are often observed in man sharply expressed disturbances of the endocrine-vegetative system—of the separate incretory organs, of the parts which effect the central regulation of vegetative functions, of the sympathetic ganglia, etc.; sometimes there are observed more delicate and complex functional dissociations of this system, which, however, distinctly influence the activity of the higher parts of the brain.

On the other hand, as we have seen, overstrain of nervous processes caused by difficult tasks and the experimentally induced nervous breakdowns brought about considerable disturbances in the activity of the vegetative nervous system, in the functioning of the internal organs; they contributed to the development of tumours and aggravated the course of the already existing diseases (intoxications).

It is noteworthy that some time after castration the disturbances of the higher nervous activity evoked by it began to level out; this emphasizes once more the high plasticity of this activity, which is able to compensate and overshadow various defects caused in the living organism.

Pavlov repeatedly referred in his works to this plasticity.

However, although in cases of castration, as already mentioned, the consequent disturbances fully disappeared, especially in representatives of the strong equilibrated types, the nervous system generally still proved to be more subject to collisions, nervous breakdowns and experimental neuroses than was the case prior to the operation; the nervous system revealed heightened fragility, delicacy and susceptibility to external noxious influences, to any functional nervous (psychical) traumatization. It is possible that for the purpose of compensation, successful equilibration, "establishment and maintenance of order" in the organism's internal medium, the pathological states artificially created in it by castration constantly demanded from the higher parts of the nervous system a certain, although externally imperceptible, straining of the nervous processes, and strained its adaptive mechanisms.

Probably this strain, continuously burdening the nervous system from within, from the internal environment of the organism, was, to a certain degree, responsible for its lowered ability to endure external difficult situations.

Certainly in their most general features all these considerations hold good for human neuroses as well. On the one hand, they must be taken into account from the point of view of the influence exerted on the nervous system by various disorders in the internal medium of the organism, in particular, in the endocrine-vegetative system, as well as in the other physiological systems; on the other hand, they must be considered from the point of view of the influence exerted on the internal medium of the organism, upon certain systems of internal organs, and, above all, on the vegetative nervous system by functional nervous (psychical) traumatization—either chronic, protracted, gradually straining and final-

ly overstraining the nervous system, or acute, abrupt, having the character of a distinct collision and producing a more or less pronounced and violent picture of a nervous breakdown.

In fact, in all cases of human general neuroses there are always in evidence the so-called "neuroses of organs," or to be more precise, various general dissociations of the vegetative nervous activity (sometimes with accentuated derangement of the functions of one or another organ), now of a more or less constant character, and now assuming the form of different vegetative crises; this is a usual phenomenon, very familiar to experienced clinicians.*

Thus, the problems raised by Pavlov before the clinic of neuroses were quite urgent, but the main role in their solution was played by the experimental investigations carried out in his laboratories.

Taking into consideration the investigations conducted since Pavlov's death by his disciples and their collaborators, we can draw the conclusion that general neuroses are diseases which affect the organism as a whole. According to their aetiology and pathogenesis they are, in some cases, the result mainly of functional nervous (psychical) traumatization, i.e., they are of a psychogenic nature and emerge under the influence of acute or protracted chronic overstrain of the higher nervous processes; in other cases they develop as a result of somatic diseases and, consequently, are mainly of a somatogenic nature.

But most frequently, perhaps, they result from the combined action of both, i.e., of injurious phenomena of a psychogenic as well as somatogenic origin, espe-

* The experimental clinical investigations conducted by Z. L. Sinkevich (1946) and T. V. Strokina (1947) showed that in fifty-five cases of general neuroses in children vegetative disturbances were observed in all of them, without exception.

cially since in the first case the disease involves, in one form or another, the vegetative nervous system (and together with it the internal medium in general), and in the second case there often appears a particular fragility of the higher nervous activity and its heightened susceptibility to psychical traumatization.

In the clinical neuroses, however, Pavlov's attention was mainly attracted by diseases of a psychogenic origin.

To what has already been said about neuroses in man and in animals the following must be added: a specific feature of human neuroses is the indispensable role played in their progressive and reverse development by that "extremely important addition," possessed by human nervous activity in contradistinction to that of animals, in other words, by the second signalling system and its interrelation with the first signalling system. This role finds expression not only in the pathogenesis and symptomatology, a fact which, as we shall see later, was first pointed out with brilliant perspicacity by Pavlov himself, but also in the prophylaxis and treatment of neuroses. The life experience acquired by the given personality in the course of its individual development—in the family, at school, in public and labour relations—formed by social influences and indissolubly connected with oral and written speech, or in Pavlov's terminology, with the "grandiose signalling medium—speech,"* is reflected and impressed in the second signalling system of the brain, as well as in its connections with the first signalling system; it exerts a substantial influence on the emergence and course of the disease, in some cases retarding its development, in others—contributing to its extinction. At the same time it should be borne in mind that all psycho-therapeutic measures influence

* I. P. Pavlov, *Lectures*, p. 356.

the patient's higher nervous activity and change it also through the medium of the second signalling system.

The experiments carried out by K. I. Platonov showed that by means of verbal suggestion under hypnosis it is possible to change the work of the internal organs and various metabolic processes. However, the limits and possibilities of the influence of the second signalling system on the vegetative nervous system are considerably broader. Experimental data obtained in our laboratory (1933-1935) proved that for a human being speech may become a conditioned stimulus, causing in conditions of full wakefulness an increase or decrease in the frequency of the heart beat, heightened blood pressure, contraction or dilatation of the eye pupils, etc., and not only when the words are pronounced by the experimenter, but even by the individual under test (L. I. Kotliarevsky, N. I. Kozin, V. K. Faddeyeva and others).

Utilizing his laboratory experience for the patho-physiological interpretation of the pathogenesis and symptomatology of human neuroses, Pavlov repeatedly modified and perfected his scientific concepts, as can be seen from the history of their development.

The experimental data obtained in the laboratory showed that morbid deviations from the normal functioning of the brain during nervous breakdowns develop in two directions: in some cases the inhibitory process (internal inhibition) is drastically weakened, in others the excitatory process suffers most.

"If now, when we have these facts, we turn our attention to human pathology . . ." Pavlov stated as far back as 1923, "we find here, on the one hand, neurasthenics, whose ability for inhibition is limited and, on the other hand, the various kinds of hysteria where inhibition is predominant and takes the form of anaesthesias, paralyses, increased suggestibility, etc. I believe that

these pathological conditions correspond to the deviation from the normal which we observed in our experimental animals."*

However, eight to ten years later (1931-1933) Pavlov's concepts changed considerably mainly under the influence of his clinical investigations.

He began, for instance, to distinguish two forms of neurasthenia: one, which involves mainly a weakening of internal inhibitors (hypersthenia), and the other—a drastic decline of the excitatory process (hyposthenia). At the same time he abandoned his previous simplified approach to hysteria** and gave a thorough and absolutely new patho-physiological interpretation of the symptomatology of this disease (he devoted a separate major work to this problem).

In 1935 in his work specially devoted to problems of experimental pathology of the higher nervous activity Pavlov wrote: "The morbid states of the nervous system, which we have produced, to a considerable extent correspond to the so-called psychogenic diseases in human beings. This same overstraining and these same collisions of the excitatory and inhibitory processes, all are experienced in our lives as well. For example, someone insults me deeply, and for some reason or other I am unable to retaliate by using corresponding words, and still less by actions, and must overcome this struggle or conflict of the excitatory and the inhibitory processes within myself.... Moreover, in addition to these neuroses, as a result of the extremely complicated make-up of our brain as compared with the higher animals, there must also be special human neuroses. I ascribe psychasthenia and hysteria to the latter."***

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 414.
** *Ibid.*, pp. 576-77.
*** *Ibid.*, 688-89.

In the same year Pavlov made the following statement, as if summarizing his work in the sphere of neuroses: "The described neuroses in dogs can best be compared with neurasthenia in human beings, especially since some neuropathologists insist on two forms of neurasthenia—excitatory and depressive. Besides, certain traumatic neuroses may correspond to them, as well as... reactive pathological states. It may be assumed that recognition of the two signalling systems of reality in man will lead specially to an understanding of the mechanisms of the two human neuroses—hysteria and psychasthenia. If, on the basis of the predominance of one system over the other, people can be divided into a predominantly thinking type and a predominantly artistic type, then it is clear that in pathological cases of general disequilibrium of the nervous system, the former will become psychasthenics and the latter hyster-

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GENERAL REVIEW OF THE INVESTIGATIONS CONDUCTED BY PAVLOV AND HIS COLLABORATORS IN THE NEUROSIS CLINIC

The general and local disturbances of the higher nervous activity described by Pavlov and his collaborators in the course of their study of experimental pathological states of the higher nervous activity caused therein by harmful functional influences, in principle hold good also for human neuropsychic diseases, and for neuroses in particular.

As already pointed out, Pavlov's attention was attracted by all three so-called major general neuroses

* *Ibid.*, p. 725.

(phychoneuroses—neurasthenia, hysteria and psychasthenia).*

In the final analysis, the concept of neurasthenia covers the three different pathological states described by Pavlov. As we already know, on the basis of his clinical observations, Pavlov came to the conclusion that, on the one hand, there are neurasthenic states in which a weakening of the processes of internal inhibition (hypersthenia) comes to the fore, and, on the other hand, states where the leading place is taken by phenomena of diffused inhibition, weakening of the excitatory process and diminution of cortical excitability (hyposthenia). But later, when describing the phenomena of pathological lability of the excitatory process, he frequently pointed out that in clinical neurology states of excitatory weakness** correspond to these phenomena, i.e., states most peculiar precisely to neurasthenia.

Neurasthenic states develop as a result of acute or prolonged overstrain of the nervous processes (in conditions of psychical and physical exhaustion, under the influence of mental or emotional overstrain, in difficult conflicting situations). More often they are encountered in representatives of the inhibitable and excitable types (i.e., with a weak and unequilibrated nervous activity), revealing no marked predominance of the first or second signalling systems, in other words, belonging, according to Pavlov, to the "intermediate human type."***

* It should be noted that over the past 20-30 years the theory of neuroses has been repeatedly "replanned"; this has led to a number of different classifications of neuroses, none of which, however, has won general recognition. Among the numerous forms thus described, neurasthenia, hysteria and psychasthenia proved, nevertheless, to be most persistent.

** I. P. Pavlov, *Twenty Years of Objective Study*, pp. 684, 729 and 734-35.

*** *Ibid.*, p. 733.

The utmost attention was devoted by Pavlov to the "hypersthenic form," which, in his view, is most inherent in the excitable type. A number of interesting remarks by him concerning the origin of this form of disease and the peculiarities of its course may be cited: "On the one hand the neurasthenic may accomplish much in life, produce some great work. Many prominent people have been neurasthenics. But together with these periods of intense activity, the neurastenic also experiences times of deep depression and feebleness."* "There are definite grounds for regarding neurasthenics, at least some of them, as strong individuals, who are even able to perform a large amount of activity.... Neurasthenics also have periods of weakness and temporary wear, and this can be easily understood, since for the most part they are continuously excited and active—and the nervous exhaustion must, of course, be made good. This type may be regarded as having different, longer periods in the sequence of activity and rest, and therefore the periods of excitation and inhibition are more accentuated in them as compared with normally balanced individuals."**

Thus Pavlov, like the prominent Soviet psychiatrist Y. V. Kannabich, was inclined to regard certain cases of neurasthenia as being close to cyclothymia.

As we see it, it is not excluded that the three above-mentioned neurasthenic syndromes actually represent different successive stages of a single pathological process.

In the first, initial, stage there is a weakening of the evolutionarily youngest and most fragile process—of the internal, active or conditioned inhibition, which, according to Pavlov, is a specific feature of the cerebral cortex. This stage is characterized by a weakening of the

* *Ibid.*, p. 469.

** I. P. Pavlov, *Lectures*, p. 348.

internal inhibitors elaborated in the course of individual development to primitive emotional and affective reactions not conforming to social demands (lack of restraint, irritability, anger), and by a decline in the inhibitory discipline of behaviour, which is usually expressed in self-control, self-possession, reserve, etc.

In the second stage the excitatory process begins to suffer: the cortex is exceedingly reactive, but susceptible to rapid exhaustion; the pathological lability of nervous excitation (easily emerging, but rapidly dying down) is characterized clinically as "excitatory weakness," along with which a heightened tiredness is usually observed.

In the third stage the upper hand is already definitely gained by phenomena of transmarginal inhibition which protect the cortical cells from too severe a strain, secure for them a state of rest and at the same time favour the processes of restorative metabolism.

Heightened inhibitability and drastically lowered reactivity of the cortex produce the clinical picture of "general asthenia."

Depending on the nature of the "psychogenic" and "somatogenic" exhaustion influences, and on the peculiarities of the types of the higher nervous activity, one of these stages may be particularly pronounced and protracted, whereas the others may not appear at all or have a rudimentary character. For example, under relatively weak noxious influences (especially in the excitable type) the disease may be confined only to the first stage; on the contrary, under considerable intensity of these influences (especially in the inhibitable type) the third stage develops almost immediately. Further research will show whether this concept is substantiated.

It should be said that in all neurasthenic syndromes there are usually observed sharply expressed disturbances of the vegetative functions, which sometimes are

accentuated in a certain system of the internal organs. Obviously, in some cases these disturbances are caused by weakening of the inhibitory regulative action of the cortex on the system of the subcortical vegetative centres, which is expressed in phenomena of liberation, disinhibition and dissociation of the vegetative functions, and in other cases by irradiation of inhibition from the cortex to the subcortical regions.

On the basis of his clinical observations and research, conducted over a long period, Pavlov gave a highly interesting and original comparative patho-physiological description of psychasthenia and hysteria; as already mentioned, he regarded them as specific human diseases of the higher nervous activity, since here the leading role, as convincingly shown by him, belongs to derangement of dynamic correlations between the first and second signalling systems of the cerebral cortex.

In the psychasthenic character he saw, as it were, an accentuated, extreme variation of the thinking type, and in the hysterical character—that of the artistic type.

In the strongly pronounced, heightened rationality of the psychasthenic, in the abundance of various, sometimes quite unnecessary inhibitors acquired by him during his lifetime, in the extreme feebleness of his instincts and inclinations, Pavlov discerned in the behaviour of this type of patient a predominance of cortical tendencies over subcortical ones. At the same time it was impossible not to recognize a tendency towards the predominance of subcortical activity over the cortical in the excessively expressed, vivid, indefatigable and heightened affectivity of the hysterics, in the insufficiency of their internal, active inhibitors often resulting therefrom, and in the faintly disguised and obviously exaggerated manifestations of their instinctive dispositions.

The painful doubts and hesitations by which the psychasthenic is often possessed when he has to act, espe-

cially under unusual, new conditions; the endless reasoning which he substitutes for quick and resolute action and for direct manifestation of his emotions, his fruitless philosophizing and mental and verbal "chewing of the cud," the poverty of his imaginative, emotional thought—all these features peculiar to the psychasthenics (most of them had already been pointed out by Pierre Janet who was the first to describe psychasthenia as an independent disease), were regarded by Pavlov as manifestations of the pathological predominance of the second signalling system over the first.

On the contrary, in the highly emotional, concrete-imaginative thinking of hysterical women, in their tendency to substitute fantasy for a rational approach to reality, in the rash, affective, impulsive actions so characteristic of them, Pavlov saw an expression of the predominance of the first signalling system over the second.

Thus, according to Pavlov, a strongly marked, morbid predominance of cortical activity over the subcortical and of the second signalling system over the first is peculiar to psychasthenia, whereas a pathological predominance of subcortical activity over cortical and of the first signalling system over the second is characteristic of hysteria.

In one of his last articles Pavlov wrote: "In psychasthenics the general weakness, naturally, affects the basic foundation of the correlations between the organism and environment, namely, the first signalling system and the emotional fund. Hence, absence of a sense of reality, continual feeling of inferiority of life, complete inadequacy in life together with constant fruitless and perverted cogitation in the form of obsessions and phobias."

Comparing hysterical persons with psychasthenics Pavlov stated in the same article: "In hysterical persons, general weakness, naturally, has a special effect on the second signalling system, which in the artistic

type in any case yields pride of place to the first system, while in normally developed persons the second signalling system is the highest regulator of human behaviour. Hence the chaotic character of the activity of the first signalling system and of the emotional fund in the form of pathological fantasies and unrestrained emotivity with profound destruction of the general nervous equilibrium (sometimes paralyses, at others contractures, or convulsive fits or lethargy) and in particular, synthesis of personality."*

As already stated, Pierre Janet, who at the beginning of the century first described psychasthenia as an independent nosological unit, regarded obsession as one of the basic symptoms of this disease; he subdivided it into obsessive ideas, obsessive movements and obsessive emotions, mostly obsessive fears or phobias.

These morbid states were termed obsessive not because they obtrude on those in the vicinity of the patient, but mainly because they are felt by the patient himself, who usually fights bitter struggles against them.

Some authors have long since regarded the syndrome of obsessive states as a separate, independent disease; during the last years of his life Pavlov also inclined to this point of view. But since these pathological phenomena are characteristic of psychasthenia, which, as we have just seen, is not denied by Pavlov either, we shall dwell on them right here.

In essence, we think that all obsessive phenomena can be divided in two groups, which, however, do not differ sharply: on the one hand, obsessive phenomena of excitation (in the intellectual sphere these take the form of obsessive ideas, concepts, recollections, desires, associations; in the emotional sphere—mostly obsessive fears or certain phobias, and in the motor sphere—obsessive

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* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 733-34.

movements and actions); on the other hand, obsessive retardations, morbid inhibitions, which prevent the patient from effecting certain movements or from acting under certain strictly definite conditions (for example, dread of elevated places or of depth; fear of narrow spaces, i.e., claustrophobia; fear of open spaces, or agoraphobia; dread of speaking before an audience, in the pupils—before their classmates, in actors—before the auditorium, etc.).

However, obsessive retardations in the performance of certain actions are often accompanied by general motor excitation (emotional excitement), by vegetative excitation (quickened pulse and respiratory rhythm, redness or paleness of the face, intensified secretion of sweat, etc.), and sometimes by panic flight. In other words, the phenomena of obsessive inhibition are easily combined with phenomena of irresistible, painful obsessive excitation.

It should be also pointed out that in some cases (perhaps even in most cases) the obsessive states are concentrated in the second signalling system, manifesting themselves in verbal notions and associations or in mental and verbal "chewing of the cud" (particularly characteristic of psychasthenia). In other cases they are of an emotional imaginative character, i.e., develop mainly in the first signalling system; sometimes they assume the character of persistent, painful imaginative-concrete and extremely vivid obsessive recollections, usually reproducing the situation which caused the patient's psychical trauma (this is peculiar to hysteria and certain psychogenic reactive states).

The above-mentioned pathological phenomena, in Pavlov's words, "may be described as stagnation, unusual inertness, heightened concentration, extreme tonicity."

Pavlov regarded the phenomena of pathological inertness of the nervous processes as the patho-physio-

logical basis of obsessive states. Some cases of "isolated pathological points," which, as we know, were experimentally caused in animals by overstrain of the excitatory or inhibitory processes, by collisions and nervous breakdowns, were regarded by Pavlov as being the simplest designs or rough models of obsessive states.

Thus, on a background of pronounced general pathological disturbance of the higher nervous activity under psychasthenia, described by Pavlov, and characterizing the deviations taking place in the interrelation of cortical and subcortical activity, as well as of the first and second signalling systems, there emerge most frequently local disturbances in the shape of certain obsessive phenomena, or phenomena of pathological inertness.

In the pathological states usually related to the so-called obsessional neurosis, the general disturbances, characteristic of psychasthenia, are either so feebly expressed that they fail to attract the physician's attention, or are even absent altogether. This does not mean, however, that in such cases general cortical disturbances are not in evidence at all: our observations show that more often than not they bear the character of irradiated, diffused induced inhibition (negative induction), caused by the functional focus of concentrated, pathologically inert nervous excitation, or, on the contrary, they manifest themselves in phenomena of pathologically intensified positive induction, connected with local disturbances in the shape of phenomena of pathological inertness of inhibition.

Consequently, in obsessional neurosis, as distinct from psychasthenia, the local disturbances come to the fore; to a considerable degree this coincides with Pavlov's interpretation of the question. But we must emphasize that even in this case the local disturbances are not fully isolated, but prove to be closely connected with certain

general disturbances in the activity of the higher parts of the central nervous system.

However, cured obsessive states, and particularly phobias, often do not fully disappear. Inhibition of these local disturbances, which bear the character of pathological inertness of the excitatory process, as well as disinhibition of obsessive retardations (phenomena of pathological inertness of the inhibitory process) are not, in many cases, durable. Under severe life situations and as a result of breakdowns, the fragile, unsteady inhibition collapses and the obsessive phenomena recur (the same is true of the disinhibition of obsessive retardations). This recurrence of formerly experienced "dreads," caused by overstrain of the cortical processes, has been described by M. K. Petrova ("phobia of depth" and other phobias).

We now turn to the patho-physiological analysis of hysteria, to which Pavlov, as already mentioned, devoted a special work and to which he frequently reverted in other articles.

At first he regarded hysteria as "an inhibitory neurosis," as a disease which manifests itself in pathologically intensified and extended phenomena of inhibition and which is characteristic of the weak inhibitable type. But accordingly as his clinical experience was enriched, he departed farther and farther from this initial point of view. At one time (in 1927) he held that "the basic feature of human hysteria is . . . weakness of the cortex";* subsequently, however, he considerably changed this point of view as well.

During the last years of his life he regarded hysterical neurosis as a derangement of proper, adequate interrelations between cortical and subcortical activities, as a marked predominance of the latter, rather than as a weakness of the cortical functions; now he spoke only

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 470.

of a relative weakness of cortical activity as compared with the subcortical, of a certain "disfunction" of the higher parts of the central nervous apparatus, which, however, can be evoked in any nervous system by a more or less protracted or abruptly emerging overstrain of the cortical processes resulting in weakening the cortex and thus leading to the predominance of subcortical activity.

Believing that hysterical neurosis is observed most frequently in reprensentatives of the weak inhibitable type and that here it takes a most severe course, Pavlov at the same time considered that "separate hysterical reactions, being of a general physiological nature, must also take place in more or less strong types under the influence of powerful stimulations or extraordinary life shocks."* But a relatively quick and complete return to normal is usually observed in these cases.

Thus hysterical neurosis may take place in representatives of the weak and the strong, in equilibrated and unequilibrated types, however, with the indispensable condition that due to these or other noxious influences there arises a dissociation, a functional incongruity between cortical and subcortical activity with the distinct predominance of the latter, and at the same time a disparity between both signalling systems.

Pavlov stated: "Usually the cerebral hemispheres, which represent the highest organ of correlations between the organism and the surrounding medium and hence the constant controller of the executive functions of the organism, always exert influence on the adjacent parts of the brain with their instinct and reflex activity. From this it follows that the elimination or weakening of the activity of the cerebral hemispheres must necessarily lead

* I. P. Pavlov, *Essay on the Physiological Concept of the Symptomatology of Hysteria*, U.S.S.R. Academy of Sciences, 1932, pp. 34-35.

to a more or less chaotic activity of the subcortex devoid of the right measure and of adequacy to the given surroundings.... The alert, active state of the cerebral hemispheres, manifested in the unceasing analysis and synthesis of external stimuli, of the influences of the surrounding medium, negatively induces the subcortex, i.e., inhibits its activity as a whole, liberating in a selective way only that activity needed by conditions of place and time. On the contrary, an inhibited state of the hemispheres liberates or positively induces the subcortex, i.e., strengthens its general activity. Consequently, there are adequate physiological grounds for the occurrence of various affective outbursts and convulsive fits in hysterical persons under acute and abrupt inhibition of the cortex resulting from unendurable stimulations—and such stimulations are not infrequent in the case of a weak cortex. These outbursts and fits are sometimes expressed in more or less definite instinct and reflex activities and sometimes in absolutely chaotic forms, depending on the varying localization of inhibition over the cortex and the adjacent or more distant subcortex."*

In addition to such abrupt disturbances assuming acute, extreme forms, the constant predominance of subcortical tendencies, in Pavlov's view, is expressed in the heightened emotivity so peculiar to hysterical persons. Strong and protracted emotional strain raises the excitability of the cortex to the functional limit and leads to the development of phenomena of transmarginal inhibition. On the other hand, the functional focus of emotional excitation evokes irradiated negative induction (induced inhibition) which merges with transmarginal inhibition and sometimes also results in irradiation of inhibition to the subcortical regions. In hysteria this

* I. P. Pavlov, *Essay on the Physiological Concept of the Symptomatology of Hysteria*, U.S.S.R. Academy of Sciences, 1932, pp. 17-18.

creates conditions favouring the emergence in the higher parts of the central nervous system of hypnotic phases, of intermediate states between wakefulness and sleep; it conditions at the same time the heightened hypnability and suggestibility of hysterical persons.

"What are suggestion and auto-suggestion?" asked Pavlov, and he gave the following answer: "They are a concentrated excitation of a definite point or region of the cerebral hemispheres in the form of a definite excitation, sensation or its trace—an idea now called forth by emotions, that is, excited from the subcortex, now produced abruptly from the outside, now by means of internal connections, associations—an excitation which acquires a predominant, undue and irresistible significance. It exists and acts, i.e., passes over into movement, into one or another motor act, not because it is maintained by various associations, that is, connections with many present and past stimuli, sensations and ideas —this would produce resolute and sensible action, such as is usual with a normal strong cortex—but because in a weak cortex with a low, weak tone this concentrated excitation is accompanied by a strong negative induction which detaches and isolates it from all indispensable extraneous influences. This is the mechanism of hypnotic and post-hypnotic suggestion. During hypnosis we observe even in a normal and strong cortex a lowered positive tone owing to irradiated inhibition. When the word or command of the hypnotist is directed to a definite point of such a cortex as a stimulus, the latter concentrates the excitatory process in a corresponding point and is immediately followed by negative induction, which, meeting little resistance on its way, spreads over the entire cortex; thanks to this, the word or command is completely isolated from all influences and becomes an absolute, irresistible stimulus, continuing to operate even subsequently, when the individual returns to an

alert state."* In this way suggestion and auto-suggestion change not only external behaviour, but evoke, more or less easily, changes in the vegetative functions, in the work of the internal organs and in the metabolic processes (since all of these even in normal conditions are dependent on cortical activity).

The fact that it is possible to suggest to a hypnotized subject anything in opposition to actual reality and to evoke in him a corresponding reaction (for example, the reaction appropriate to a bitter taste when the reality is a sweet taste, the perception of a blue light when the reality is a yellow light, etc.), was regarded by Pavlov as being a manifestation of the paradoxical phase, when weaker (verbal) stimuli produce a more powerful effect than strong (direct, real) stimuli.

The phenomena of echokinesis and echolalia observed in a hypnotic state were interpreted by Pavlov as a disinhibition with a simultaneous inhibition of the higher functions.

"Hypnosis," he said, "strikingly reproduces the imitative reflex which in childhood forms and develops in all of us the complicated individual and social behaviour."** Consequently, a state of this kind is regarded by Pavlov as being one of the hypnotic phases.

We already know that the phenomena of catalepsy were also interpreted by him as a hypnotic state. Hypnotic states, in Pavlov's view, are a partial sleep of the higher parts of the central nervous system—partial in respect to depth (transitory or intermediate phases between wakefulness and sleep) and localization—sometimes spreading only over the motor analyser, and some-

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* I. P. Pavlov, *Essay on the Physiological Concept of the Symptomatology of Hysteria*, U.S.S.R. Academy of Sciences, 1932, pp. 21-22.

** I. P. Pavlov, *Lectures*, p. 356.

times descending only to definite levels and parts of the brain stem.

The fantasies of hysterical persons and the twilight states not infrequently observed in them are also ascribed by Pavlov to intermediate states between wakefulness and sleep. Hysterical analgesia, anaesthesia, paresis and paralysis were, in turn, defined by him as inhibitory symptoms, as manifestations of partial, local sleep.

Strong stimuli and emotiogenic perceptions evoke in hysterical persons an extremely concentrated excitation with a considerable negative induction, and for a long time (often even forever) they are impressed and fixed in the cortex (through the same mechanism as in hypnosis).

The following disturbances were regarded by Pavlov as being particularly characteristic of hysteria: "Quick susceptibility to different degrees of hypnotic states due to the fact that even normal life stimuli are super-powerful and are accompanied by transmarginal diffused inhibition (the paradoxical phase); extreme fixation and concentration of the nervous processes in definite points of the cortex due to the predominance of the subcortex; and, finally, undue intensity and extensity of negative induction, i.e., of inhibition caused by low resistibility of the positive tone of other cortical parts."*

Before we leave the question of the patho-physiological foundation of general neuroses we must dwell, although briefly, also on the local disturbances which often persist after hysterical reactions or after other psychogenic reactive states and which represent their more or less prolonged after-effects.

Pavlov himself mentioned these states: "There are various morbid states of the nervous system in man in which normal activity is more or less maintained only

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* Essay on the Physiological Concept... pp. 32-33.

so long as the man is not affected by any, sometimes very negligible, components, even in the shape of verbal hints, of those strong and complex stimuli which originally evoked the nervous disturbances."*

Collisions and nervous breakdowns caused by overstrain of cortical processes produce phenomena of certain neuroses or neurotic psychogenic reactions, but in the end recovery sets in. However, the cortex retains for a long time the "pathological point" or, to be more precise, the pathological dynamic structure, which reflects the formerly experienced psychical trauma or severe life situation. Even a remote hint, the slightest imprudent touch to the "pathological point," is sufficient to revive the neurotic picture, although usually for a brief period. Thus, the local disturbance, which stubbornly persists after recovery, easily becomes a source of relapse, a cause of new outbursts. The proper correlations between the excitatory and inhibitory processes in the cortex become deranged; phenomena of diffused inhibition and phasic states arise, reproducing the initial picture of the nervous breakdown. In essence we have here relatively compensated forms of the disease. We have repeatedly seen the simplest models of such cases, especially in the experiments of V. V. Rickman and M. K. Petrova.

We have not only written in detail about the basic principles and trends of Pavlov's research in clinical neurosis, but at the same time we have continued to the best of our abilities research in the same direction on the basis of our own observations.

This work includes: formulation of the principal tasks of research into the patho-physiology of the human nervous activity; description of the adaptation to new surroundings peculiar to the various types of nervous system; observations on the dynamics of development and

* I. P. Pávlov, *Lectures*, p. 351.

sequence of neurasthenic syndromes; attempts to systematize and patho-physiologically to analyse obsessive states; considerations concerning hysterical neuroses and their after-effect, etc.

Concluding, we shall briefly touch on the investigations carried out by the neurosis clinic in which Pavlov conducted his experimental work, as well as on the investigations performed by the laboratory built at this clinic for the purpose of studying higher nervous activity.

This laboratory worked out a number of methods for experimental investigation of human nervous activity, in particular, the methods of photo-chemical reflexes of the eye, of eyelid conditioned reflexes, etc. (B. V. Andreyev, A. O. Dolin, F. P. Mayorov, and others). However, the main job was study of the pathological forms of sleep. The basic methods used were: the method of chronaxy (F. P. Mayorov), partially, the method of graphic registration of changes in muscular tone during sleep (A. N. Pakhomov) and registration of the movements of the eyelids (B. V. Andreyev).

The study of motor chronaxy revealed a number of consecutive changes which take place in it accordingly as the sleep becomes deeper and deeper; these changes are manifested in the following phases: the phase of shortened chronaxies, the phase of divergent chronaxies (the scissors phase), the phase of protracted chronaxies, the phase of equalization of chronaxies of the antagonists, and the phase of inverse relations between chronaxies of the antagonists at a high level (F. P. Mayorov).

Close attention was devoted to the phenomena of hypnosis. The investigations revealed a weakening of the hypnotic sleep at the moment of verbal suggestion (B. V. Andreyev), a decline in the working capacity of the cerebral cortex in a hypnotic somnambulic state (M. M. Suslova), depression of the vegetative functions during prolonged and deep hypnotic sleep (Y. L. Schrei-

ber); finally, the individual experience of the patient's personality impressed in his cerebral cortex was studied by means of hypnotic suggestion, which produced, as it were, the reversion of the patient to certain earlier stages of his life (A. O. Dolin, F. P. Mayorov).

B. N. Bierman carried out a thorough study of the nervous mechanisms of hypnotic suggestibility under various neuroses and showed that it depends not only on the peculiarities of the cortical dynamics (heightened inhibitability), but also on the correlations between cortex and subcortex. In his view, the hypnotic suggestibility test is one of the methods by which the type of higher nervous activity in man both in normal conditions and in a state of neurosis may be defined.

Practice showed that small doses of bromides (sodium bromide in 0.5-2% and 5% solutions) produce a favourable effect on neurotics; however, such treatment requires precise and individually adapted dosage (B. N. Bierman).

"In our clinic, too," wrote Pavlov, "the neuropathologists have already noticed that successful treatment requires, in many cases, not an increase but a reduction of doses of bromides, down to decigrammes and centigrammes per dose."*

Later a combination of bromide and caffeine was also successfully practised in clinical treatment, and after the last war sleep therapy was applied to neurotics with favourable results (B. N. Bierman).

The war, and the blockade of Leningrad in particular, directed the attention of the clinic to war-time trauma and hypertensive illness. Study of the pathologically fixed defensive reactions and defensive postures of the head or of the whole body under war wounds showed that these symptoms are explained by phenomena of the

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 692.

pathological fixedness of the excitatory process in the kinesthetic analyser of the cortex (F. P. Mayorov); it also emphasized the significance of psychical traumas for the aetiology of the hypertensive illness, which are chiefly explained by "the inertness of the vegetative vasomotor centres" (L. B. Gackel).

Thus, in a number of its researches the clinic carried forward the elaboration of Pavlov's ideas in the sphere of patho-physiology and treatment of neuroses, as well as of related pathological states of the higher nervous activity.

6

THE BASIC PRINCIPLES OF PAVLOV'S PATHO-PHYSIOLOGICAL WORK IN THE PSYCHIATRIC CLINIC

Now we proceed to Pavlov's work in his psychiatric clinic. "Besides elucidating the mechanism of neuroses," he said, "the physiological study of higher nervous activity provides the clue to an understanding of certain sides and phenomena in the pictures of psychoses."*

In the psychiatric clinic Pavlov's attention was attracted now by separate symptoms, now by different symptoms-complices and syndromes, and sometimes by those and other diseases.

In all cases he always tried to understand the neurodynamic substrate and to explain from a patho-physiological standpoint the "psychotic derangements" under observation, which are usually described from the psychopathological aspect.

A feature of Pavlov's patho-physiological approach to these phenomena was that he often discerned common features in them, whereas for the clinicians only the differing features were obvious and unmistakable. However,

* *Ibid.*, p. 725.

this does not mean that Pavlov overlooked the differences, that he did not endeavour to explain them. For example, he found common features in such different phenomena as the motor stereotypies and hallucinations. in negativism and in certain forms of delirium, etc.

We shall first dwell on the patho-physiological interpretation of separate symptoms.

"In my view," said Pavlov, "it is possible to assume that in stereotypy, iteration and perservation, as symptoms . . . there is one and the same underlying patho-physiological phenomenon, namely, that which we observed in our experiments and which was termed by us "pathological inertness." Stereotypy, iteration and perservation represent pathological inertness in the motor area of the cortex (both of the general skeletal and special speech movement). . . . The emergence of a similar pathological state also in the lower parts of the central nervous system must not, of course, be excluded. . . . Pathological inertness in the motor sphere now manifests itself in definite points, now embraces the whole of the skeleto-muscular system, as can be observed in certain catatonics in whom any group of muscles, passively set in motion, repeats the given movement many times over."*

However, phenomena of pathological inertness of the excitatory process, as we already know, can be observed not only in the sphere of movement, but also of perception, i.e., in the different areas (analysers) of the cerebral cortex receiving exteroceptive and interoceptive stimuli, and not only in the first, but, in the case of man, also in the second signalling system.

Concerning the causes evoking the pathological inertness—a subject to which we will turn a little later—Pavlov said: "The above-mentioned causes could concentrate the pathological inertness of the excitatory

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* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 640-41.

process in different structures of the cerebral cortex—sometimes in the cells which directly receive stimuli both from external and internal agents (the first signalling system of reality) and sometimes in the different cells (kinesthetic, auditory and visual) of the speech system (the second signalling system); in both cases this concentration may be of different intensity, now at the level of notions, now reaching the force of actual sensations (hallucinations)."*

Thus, Pavlov explains hallucinations also by phenomena of pathological inertness, in which local disturbances may take place either in the first signalling system (imaginative hallucinations), or in the second (verbal hallucinations); sometimes they take place simultaneously in both systems (complex imaginative-verbal hallucinations). However, phenomena of pathological inertness of the excitatory process are not always responsible for the hallucinations; but to this question we shall revert later.

As we already know, states of obsession were also attributed by Pavlov to pathological inertness; unfortunately he did not give any concrete indications as to their localization in the cortex. But if we recall his statements concerning the "dynamic structural complexes," we believe it would not be erroneous to assume that states of obsession are explained by phenomena of pathological inertness related to the complex dynamic structures of the connections linking the different areas and systems of the cortex and only in separate cases relating predominantly now to one of them, now to another. To a certain degree, this, in all probability, also applies to the more complex hallucinations.

Consequently the nature of neuropsychical derangement evoked by phenomena of pathological inertness

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* *Ibid.*, pp. 644-45.

changes qualitatively, depending on the varying localization of the inertness.

A number of psycho-pathological symptoms-complices and syndromes can be explained patho-physiologically on the basis of Pavlov's conceptions regarding the depth and localization of the inhibitory process in the motor areas of the brain under different pathological processes.

We already know that in the development of phasic states, inhibition, while leaving all other areas of the cortex unaffected, may concentrate in the motor analyser and then irradiate to different levels of the brain stem (to the subcortical motor centres).

"We must assume," Pavlov said, "that a movement proceeding from the motor analyser, as is the case in general, consists of two opposite innervations—positive and negative, a movement towards the object and a movement away from the object, similar to the relations of the flexors and extensors in the limbs."* Naturally, the relations of these movements are those of induction, i.e., when one of them becomes excited, the other inhibited.

Now, if we assume that the motor area of the cortex (and perhaps the lower motor regions too) go over to the state of the ultra-paradoxical phase, then the conditions which previously caused a positive motor reaction will evoke a negative reaction, and, on the contrary, those which caused a negative reaction will evoke a positive one.

In other words, in the ultra-paradoxical phase in the motor analyser we meet with phenomena of *negativism*.

Under complete inhibition of this area we shall observe a *stuporous state*; depending on the level of the brain stem, to which the inhibition irradiates, and on the motor-co-ordinating systems which it embraces, this state

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 526.

will be accompanied by phenomena of *catalepsy* (waxy rigidity), by general muscular torpor or by general hypotonia.

At a certain depth of diffused inhibition (one of the phasic hypnotic states) embracing the first and second signalling systems, there takes place a liberation, disinhibition of the physiological imitative reflexes that exist in childhood and there emerge phenomena of *echokinesis* and *echolalia.*

As we have seen, Pavlov attributes various twilight states to intermediate states between wakefulness and sleep (hypnotic phases). To this we must add that in twilight, as well as in confused states, the inhibition least of all spreads to the motor area (on the contrary, in some cases the latter appears to be positively induced by it), and most of all to the second signalling system, since evolutionarily this is the youngest and most susceptible to injury.

It should be added that the nature of the syndromes of the twilight and confused states greatly depends on the state of the subcortical regions which are also sometimes inhibited and sometimes produce phenomena of extreme excitation.

Of all psychoses the manic-depressive psychosis, paranoia, and particularly schizophrenia, attracted Pavlov's interest most of all. And of these schizophrenia, more than any other, attracted his attention and was most profoundly studied by him.

Pavlov's statements concerning the manic-depressive psychosis were based both on clinical observation and on the experimental data obtained in the laboratory, and showed that pathological states of the higher nervous system artificially induced in animals not infrequently assumed a periodic, circular character.

Pavlov believed that, in conditions of overstrain of the nervous system caused by severe external conditions of

internal somatic disorders, the circular psychosis is particularly characteristic for the excitable type. Since this type "lacks a proper abating and restorative process, the process of inhibition, its excitatory process often considerably exceeds the working capacity of the cortical cells. This is responsible for the derangement of the proper sequence of normal work and normal rest. . . . Hence, in particularly difficult conditions of life or under certain conditions unfavourable for the organism, there sets in, finally, a manic-depressive psychosis."*

It is worth noting that Pavlov did not adhere to the point of view generally accepted in psychiatry which regarded this disease as an endogenic psychosis; he stressed the significance of exogenic influences.

According to Pavlov, the increased excitability of the nervous system creates highly favourable conditions for the development of certain forms of neurasthenia, on the one hand, and of cyclothymia and circular psychosis—on the other. But whereas in neurasthenia insufficiency of the inhibitory process relates to active (internal) inhibition, in circumstances of cyclothymia and especially circular psychosis in the periods of excitation (hypomanic states) there is manifested, in addition to a weakening of active (conditioned) inhibition, an insufficiency of what Pavlov termed "the abating and restorative process," which is normally transmarginal inhibition—one of the forms of passive (unconditioned) inhibition.

Paranoia and certain paranoid psychoses ("sensitive delirium") allied to schizophrenia, among other psychoses, aroused Pavlov's interest.

Surprising as it may seem at first sight, Pavlov discerned common features in obsessional neurosis and paranoia (it should be recalled, however, that at the end of the last century and at the beginning of this century psy-

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 677.

chiatrists pointed to the existence of a psychosis of obsessive ideas—*psychosis ideo-obsessive*). In both diseases Pavlov's attention was arrested by the peculiar "isolation, separation, disunion" of the pathological phenomena, bearing the character, as it were, of local disturbances and existing on the background of a fully intact and often relatively high intellect, in the absence of any symptoms of decomposition of the personality and of any process leading to feeble-mindedness. Outside the system of his delusion (persecution delusion or delusion of grandeur), when the conversation does not touch on "pathological points," a paranoiac can produce the impression of an absolutely healthy individual (this, of course, fully applies also to people suffering from obsessive phenomena).

It goes without saying that from the point of view of the clinician, the difference between paranoia and obsessional neurosis is very considerable and profound (recall, for instance, the critical attitude displayed by the obsessional neurotic to his illness, in contradistinction to the paranoiac; the struggle waged by the former *against* his morbid ideas, and the violent struggle of the latter *for* his delirious ideas).

Since we have already given much attention to obsessional neurosis when dealing with general neuroses, we shall now concentrate only on paranoia.

"...One can hardly dispute," Pavlov wrote, "that while pathological inertness is manifest and must be recognized as a matter of fact in motor phenomena, the same is quite possible and natural in respect to all sensations, emotions and ideas. Who can doubt that normally the above-mentioned phenomena are, of course, a manifestation of the activity of the nerve cells and that, consequently, obsessional neurosis and paranoia represent a pathological state of corresponding cells of the cerebral

cortex, and in this particular instance, their pathological inertness."*

Proceeding from Pavlov's concept, we can assume that a complex patho-dynamic structure of cortical connections or associations conforms to the systematized delusion of the paranoiac, a structure, in a selective way embracing different areas of the cerebral cortex and highly affective (which is connected also with powerful subcortical impulses). Precisely in this structure the phenomena of pathological inertness of excitation emerge together with inevitable decline of the inhibitory processes. This steady diminution of active inhibition takes place parallel with the development of a systematized persecution delusion bearing the character of a pathological dominant.** Together with the final decline of inhibitory corrections, "there sets in the absolute power of an idea which, not through active inhibition on the basis of other associations, other signals, signals of reality, but through passive inhibition, through a process of negative induction, excludes everything not in keeping with it and turns into a fantastic idea of imaginary grandeur, imaginary success."***

Thus, in the dynamic structure underlying the delusion, there are manifested with steadily increasing intensity, phenomena of pathological inertness of the excitatory process, "around which (on the basis of the law of generalization) all that is near, related and similar is concentrated, and from which (according to the law of negative induction) everything alien to it is checked or repulsed."****

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 641.

** As far back as 1925, an attempt was made by us to elucidate the pathogenic mechanism of paranoia from the point of view of the theory of higher nervous activity and the theory of dominant.

*** I. P. Pavlov, *Twenty Years of Objective Study*, p. 647.

**** *Ibid.*, p. 650.

Consequently, paranoiac delusion is explained by phenomena of pathological inertness of excitation with a steady diminution of inhibitory corrections (internal active inhibition).

As a consequence, in paranoia "we meet with excessively, unduly persistent ideas, sensations and also actions which do not conform to the correct natural and specifically social relations of man, and which therefore bring him into severe, harmful conflict both with nature and other human beings and, above all, of course, with his own personality. But this applies only to pathological ideas and sensations; outside their sphere the patients think and act like perfectly normal individuals, and may even represent subjects higher than the average level."*

In the aetiology and pathogenesis of paranoia Pavlov attached great importance to overstrain of the excitatory process and to the collisions of the excitatory and inhibitory processes formerly experienced by the patient. On the other hand, he pointed to the possibility of abnormal development or of a temporary derangement of instinctive activity; finally, he assumed that the pathological state "of a certain internal organ or of an entire system may send a steady or an excessive stimulus to the corresponding cortical cells for a definite period of time or permanently, and in this way produce in them finally pathological inertness—a persistent idea or sensation, when subsequently the real cause already ceased to act. . . . Our second reason was also bound to produce no less, and perhaps even more, cases of pathological inertness, since our entire life is an endless struggle, a conflict of our basic ambitions, desires and tastes both with the general natural conditions and the specifically social conditions."**

Pavlov considered pathological inertness responsible

* *Ibid.*, p. 641.
** *Ibid.*, p. 644.

also for the phenomena of "mental or cerebral automatism," which have been described by the French psychiatrist Clérambault and include certain forms of hallucinations, the so-called "phonation of thoughts," etc.

Observing in the clinic some cases of paranoid (delirious) psychoses similar to those characterized at one time by Kretschmer as "sensitive delirium," and especially in connection with the article of Pierre Janet concerning "emotions of the persecution delusion," published in 1932, Pavlov noted that some delirious patients, while stubbornly ignoring reality, rejecting and suppressing the sound and natural associations evoked by it, consider reality their desires and apprehensions which formerly for some reasons were rejected by themselves or by the surroundings and thus were suppressed, inhibited.

Hence, within a certain complex of their relations with other human beings these patients behaved not in conformity with the demands of reality, but proceeding from their previously suppressed desires and apprehensions, which now appeared to them as having been realized. For instance, a girl who at one time longed to have a child, but fearing to have it born out of wedlock, later abandoned her desire as infeasible and remained sexually intact. Then suddenly she began to assert that she was pregnant. Pavlov ascribed such forms of delusion to phenomena of the pathological ultra-paradoxical phase, when natural, normal associations, caused by reality and adequately reflecting it, are rejected, suppressed, inhibited, and the previously rejected, suppressed and inhibited associations are disinhibited, abnormally intensified and contrary to the reality, begin to govern the behaviour and speech of such patients.

"There are cases," Pavlov wrote, "when the patient irresistibly regards as reality that which he fears and wants to avoid. For instance, he wants to have a secret and it appears to him that all his secrets are constantly

being disclosed in some way. He wants to be alone, and even though he is alone in his room and everything lies open before his eyes, he still imagines that someone else is there with him. He wishes to be respected and it seems to him that at every moment he is being insulted in some way or other by words, signs or facial expressions. Pierre Janet has described this as feelings of possession, as if somebody is taking hold of the patient. In my view this case is based physiologically on the ultra-paradoxical phase. . . ."*

Thus, proceeding from the pathological disturbances of the neuro-dynamics, the basis of delusions, Pavlov discerned in them two different forms. However, a strong and protracted pathological excitation of these or other cortical dynamic structures, as a consequence of even a delayed, pathologically weakened transmarginal inhibition, may, sooner or later, lead to the development in such structures of phasic phenomena, including the ultra-paradoxical phase. Then one form of delusion is succeeded by the other.

"Thus, two physiological phenomena underlie delusions," said Pavlov, "pathological inertness and the ultra-paradoxical phase which sometimes manifest themselves simultaneously and sometimes supersede each other."**

In his view clinicians, neurologists and psychiatrists working in their respective spheres, should unhesitatingly regard the following patho-physiological facts as fundamental: in the first place, isolation of the functionally pathological (in respect of aetiology) points of the cortex, understanding this, however, not only "in the crude anatomical, but also in the structurally-dynamic sense";***

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 699.

** *Ibid.*, p. 649.

*** *Ibid.*, p. 699.

secondly, the phenomena of pathological inertness of the nervous processes in such dynamic structures; and thirdly, the ultra-paradoxical phase in them.* In this way Pavlov concluded his article representing an essay on the physiological concept of obsessional neurosis and paranoia.

7

PAVLOV'S RESEARCH INTO THE DISTURBANCES OF THE HIGHER NERVOUS ACTIVITY UNDER SCHIZOPHRENIA

Pavlov tackled the problem of the patho-physiology of schizophrenia in a number of his works; in some of them he touched on it only in passing, in others in greater detail, while some works were wholly or almost wholly devoted to this subject.

In one of his first articles relating to this problem, Pavlov, before going on to speak about schizophrenia, gives a brief introduction which is of great help for a proper understanding of his fundamental patho-physiological views on this complex disease—a disease which to this day remains so little described as to its pathogenesis and which actually embraces a considerable group of psychoses resembling one another only in certain respects.

Dissociations of the brain activity take place not only in the cerebral hemispheres, but also in the lower parts—in the systems of the subcortical centres and at the same time in the interrelations between the cortex and subcortical regions, thereby causing a number of complex and diverse pathological pictures.

"One can easily understand how great this diversity

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 650.

must be in man."* But even within the limits of a single disease, especially a disease like schizophrenia, this diversity is quite considerable, which greatly complicates patho-physiological research.

"On the background of the general crude activity, affected by the subcortical centres, the cortex in a way embroiders a pattern of more delicate movements, ensuring maximum conformity with the conditions of life... The subcortex, in its turn, exerts a favourable influence on the cortex of the cerebral hemispheres, acting as the source of their power."**

But this occurs only in the optimal dynamic correlations between the cortex and the subcortical areas. When, however, these correlations are above or below optimum, phasic phenomena develop in the cortex (equalization, paradoxical, ultra-paradoxical and other hypnotic phases); and, in keeping with any deviation from the optimum, there arise steadily growing phenomena of inhibition. This is explained by the fact that with increased excitability "the strongly excited subcortex highly charges the cortex and intensifies the lability of the cells; in these conditions strong stimuli grow into ultra-powerful ones, evoking their own inhibition."*** On the contrary, in lowered excitability, i.e., when the impulses coming from the subcortex diminish, "the lability of the cortical cells declines, mostly of the cells which previously performed a greater amount of work; naturally, these are the cells to which the strong stimuli were addressed."****

"Summing up all that has been said concerning the correlation of cortical and subcortical activity," wrote Pavlov, "we can say that the subcortex is the source of

* I. P. Pavlov, *The Physiology and Pathology of the Higher Nervous Activity*, State Medical Publishing House, 1930, p. 27.

** *Ibid.*, p 29.

*** *Ibid.*, p. 30.

**** *Ibid.*, pp. 30-31.

energy for the entire higher nervous activity, the cortex playing the role of regulator of this blind force, skilfully directing and repressing it."*

It should be emphasized, however, that the activity of the cerebral cortex in man is constantly regulated by social influences, which induce, direct and inhibit this activity and simultaneously the subcortical functions controlled by it.

According to Pavlov, the more specific properties of schizophrenia include heightened inhibitability of the cerebral cortex, phenomena of diffused inhibition the intensity and localization of which in the higher parts of the brain are changeable, and which is accompanied by various phenomena of liberation, disinhibition, positive induction of the evolutionary older, primitive and even rudimentary functions; another feature consists in transitory, intermediate states between wakefulness and sleep closely connected with this inhibition, now mainly of a general, now of a particular nature (i.e., having the character of local disturbances), in other words, the so-called hypnotic states (which Pavlov, as we know, usually distinguished by their intensity and extensity).

Pavlov considered these peculiarities of schizophrenia to be closely connected with another, no less specific property (later we shall see how he connected them). In one of his articles he wrote: "How may we consider the extreme general weakness of the cortex, so to speak, its pathological, abnormal fragility?" In such a cortex functional difficulties will evoke "isolated pathological points and foci," or, in other words, pathological dynamic structures showing a tendency towards destruction. "In schizophrenics, because of the influence of more or less difficult life experiences and probably because of organic disease,

* I. P. Pavlov, *The Physiology and Pathology of the Higher Nervous Activity*, State Medical Publishing House, 1930, pp. 31-32.

gradually and constantly there appear an ever-increasing number of such weak points and foci, and, by degrees, a break-up of the cerebral cortex takes place, a splitting of its normally unified function."*

Pavlov's first acquaintance with the psychiatric clinic (1918) began with a study of catatonic syndromes; it should be stated that his first steps in this new field proved extremely fruitful and of great significance for the formation of his further views on the patho-physiological basis of schizophrenia.

Already then, i.e., in 1918, his attention was particularly attracted by cases of catatonic stupor (in one case the phenomena of complete immobilization and complete dumbness—mutism—lasted twenty-two years and ended in recovery of the patient when he was sixty years old. Recalling his state of stupor, the patient said that he had been conscious of his surroundings, but had been unable to react, since, in Pavlov's words, he "experienced such extreme and insuperable heaviness in his muscles that he could hardly breathe").

Concerning the cases of partial, isolated inhibition of the motor analyser, frequently observed in his laboratories, Pavlov wrote: "Thus, in the patients described above we have enough evidence also to affirm the existence of a concentrated and isolated inhibition of the motor area of the cerebral cortex, caused by the factor which brought on the illness."**

At that time he regarded the phenomena of catalepsy and the tonic reflexes, observed by him under states of catatonic stupor, as "a manifestation of the normal activity of the lower parts of the motor nervous apparatus, while the functions of the higher parts of the cerebrum are inhibited.

I. P. Pavlov, *Twenty Years of Objective Study*, p. 470.
Ibid., p. 354.

This exclusion of functions, in Pavlov's words, "all the time was of a functional rather than of an organic, pathologico-anatomic nature."*

Further, Pavlov noted that this inhibition affects only the motor nervous elements and spreads only to the motor sections of the brain.

Concerning the reasons for these disturbances in the work of the nervous system, he wrote: "Different assumptions are, of course, possible. There may be a definite toxic action, whose sphere of influence is naturally limited by the individual peculiarities of the separate cortical elements. One can also assume exhaustion of the elements of the cortex resulting either from the general exhausted condition of the organism, or only from overfatigue of the brain, from exhaustion concentrated in definite elements of the brain either because of the particular part of these elements in the work producing the exhaustion, or again as a result of their specific nature. Finally, there is the possibility of direct or indirect (the last resulting from local changes in blood circulation or in general nutrition) reflex influences which may affect injuriously and also in an elective manner different elements of the cortex. Hence, in different cases, in spite of the similarity or even identity of the mechanism of the given complex of symptoms, the causes producing them may not be the same."**

It is interesting to note that the assumption made by Pavlov more than thirty years ago concerning the diversity of the origin of catatonic states was subsequently confirmed by numerous observations and experiments. Today we know that catatonic states can be caused not only by such specific agents as alkaloids, for instance, by bulbocapnine and mescaline, but also by definite doses of certain convulsive agents, like cardiazol, by definite doses

* I. P. Pavlov, *Twenty Years of Objective Study*, p. 355.

** *Ibid.*, pp. 356-57.

of insulin or by the hormone of the parathyroid glands. They may arise in cases of traumatic lesions, vascular, intestinal diseases, etc.

No less diverse, apparently, is the aetiology of the considerable group of diseases covered by the general concept of schizophrenic psychoses.

Much later, when Pavlov again turned to the problems of schizophrenia and engaged in a more detailed study of it (in the early thirties), he concentrated mainly on catatonic syndromes, devoting considerably less attention to the paranoid form (we have already touched on his pathophysiological concept of paranoid psychoses), and still less attention to the hebephrenic form.

Concerning the different catatonic and partly hebephrenic symptoms he stated: "Inhibition, which together with excitation constantly takes part in the diverse activity of the animal in its wakeful state, also guards the extremely reactive cells of the organism, the cells of the cerebral cortex; it protects them from highly strenuous work under the action of very strong stimuli, or even under the prolonged repetition of weak stimuli; it also ensures the necessary rest for the cells in the form of sleep after their daily normal work.

"We have established the indubitable fact that sleep is inhibition, which irradiates over the hemispheres and descends along the brain to a certain level. Besides, we have been in a position to study on our animals also the intermediate phases between wakefulness and complete sleep—the hypnotic phases. These phases have been regarded by us, on the one hand, as different degrees of extensity of inhibition, i.e., of a larger or smaller extent of its irradiation over various areas of the hemispheres, as well as over various parts of the brain, and, on the other hand, as different degrees of intensity of inhibition in the form of different depth of inhibition in one and the same point. It is clear that owing to the tremendous

complexity of the human brain, the diversity of separate hypnotic phenomena in man is much greater than in animals. However, it is possible that some hypnotic phenomena are for one reason or another more manifest in animals than in man.... And so, taking into consideration the full complex of symptoms of hypnosis, I shall further deal with hypnotic phenomena observed both in man and in our animals.

"Observing the above-mentioned schizophrenic symptoms I have come to the conclusion that they are an expression of a chronic hypnotic state...."*

However, we must emphasize once more that Pavlov attributed special importance to hypnotic phases; in his view they represent partial, incomplete sleep, transitory or intermediate states between full wakefulness and full sleep.

Pavlov was the first to notice the following interesting symptom which is of practical importance for clinicians: in some cases of catatonic stupor with complete immobilization and mutism, the patient who did not react at all to the questions addressed to him, began to answer the same questions when they were asked not in a loud but a low voice, or even in a whisper. In this way it was established that phenomena of the *paradoxical phase* are observed in some stuporous states.

In the clinic it often happens that late in the evening or at night, when absolute silence sets in and there are no strong auditory or visual stimuli in the surroundings, some stuporous catatonics become disinhibited: they begin to move about in the ward, to eat, drink and sometimes even to talk (a case of this kind was described in detail by Pierre Janet).

In Pavlov's view, this is also a manifestation of the paradoxical phase (the action of weak stimuli).

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* I. P. Pavlov, *The Physiology and Pathology of the Higher Nervous Activity*, State Medical Publishing House, 1930, pp. 38-39.

We already know that the phenomena of negativism so characteristic of catatonics were regarded by him as the *ultra-paradoxical phase* in the motor parts of the brain, and catalepsy—as the liberation, disinhibition of complex unconditioned reflexes of the equilibration of the body in space when the higher motor parts of the brain are inhibited; likewise he regarded the phenomena of general muscular rigidity as a disinhibition of the tonic reflexes.

We have already touched on Pavlov's interpretation of the phenomena of echopraxia and echolalia.

In strong outbursts of motor catatonic excitation ("violent agitation of the subcortex") he saw a disinhibition of the subcortical centres adjacent to the cortex, combined with a profound inhibition of certain cortical areas; in the phenomena of hebephrenic playfulness and silly mannerisms it is not difficult to distinguish a similar disinhibition of the ontogenically earlier functional levels of the cerebral activity under simultaneous inhibition of its later functional levels. Pavlov compared these phenomena with the initial stages of alcoholic narcosis.

Thus he regarded various clinical pictures, observed mainly under the catatonic form of schizophrenia, as different, lasting and chronic intermediate states between wakefulness and sleep (hypnotic phases). In the final analysis, of course, this hypnosis is profoundly based on the weak, nervous system, and especially the weakness of the cortical cells. For this weakness various causes, both hereditary and acquired, may be responsible. "We shall not touch here on these causes," said Pavlov in 1930 (later, as we shall see, he did touch on them). "But naturally when such a nervous system encounters difficulties, more often in a critical physiological and social period of life, it inevitably becomes exhausted after excessive excitation. But exhaustion is one of the chief

physiological impulses for the appearance of inhibition in the capacity of a protective process. Hence chronic hypnosis is inhibition in different degrees of extensity and intensity. Consequently, this state is, on the one hand, pathology, since it prevents the patient from normal activity, and on the other hand, according to its mechanism, it is still physiology, a physiological remedy, since it protects the cortical cells from the danger of being destroyed as a result of too heavy work.... There are reasons to assume that as long as the inhibitory process operates, the cortical cells are not gravely damaged, their full return to normal is still possible, they can recover from excessive exhaustion and their pathological process remains reversible. Using modern terminology, it is only a functional disease."*

In this connection Pavlov recalls that, according to Krepelin's statistical data, of all basic forms of schizophrenia the catatonic form shows the highest rate of recovery. "Thus," Pavlov wrote in 1930, "there are already sufficient grounds for regarding certain symptoms of schizophrenia as a manifestation of the inhibited state of the cortex, as a kind of protection of the nervous cells up to a certain point against further exhaustion."**

Proceeding from this concept, Pavlov was inclined to regard many cases of schizophrenic general and local motor excitation as being phenomena of central excitation, caused by a destructive process due to insufficiency, decline or complete exhaustion of the protective inhibitory remedies of the nervous system. It is absolutely clear that in these remedies he saw not "a purposeful activity," but a philogenic protective nervous mechanism elaborated in the course of evolutionary development.

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* I. P. Pavlov, *The Physiology and Pathology of the Higher Nervous Activity*, State Medical Publishing House, 1930, pp. 43-44.

** *Ibid.*, p. 34.

One can easily understand that these concepts of Pavlov are both of prognostic and curative significance for the clinic, to which subject we shall revert later on.

In 1935, i.e., one year before his death, Pavlov summed up his views on schizophrenia as follows:

"It must be said that in experimental diseases of the nervous system there are almost constantly observed separate phenomena of hypnosis, and this gives us the right to assume that it is a normal way of physiological struggle against morbific agents. Hence, the catatonic form or phase of schizophrenia, consisting entirely of hypnotic symptoms, can be regarded as physiological protective inhibition limiting or fully excluding the activity of the diseased brain, which, owing to the action of a certain, still unknown, noxious agent, is threatened by a serious disturbance or complete destruction. Medicine knows very well that the first therapeutic measure, which must be applied in the treatment of almost every illness, is to ensure a state of rest for the diseased organ. That such a concept of the mechanism of catatonia in schizophrenia conforms to reality, is convincingly proved by the fact that only this form of schizophrenia shows a considerable rate of recovery, despite the protracted character of the catatonic state, which sometimes persists for years (twenty years). From this point of view any attempt to act on catatonics by means of stimulating methods and remedies is definitely injurious. On the contrary, a very considerable increase in the rate of recovery can be expected when physiological rest (inhibition) is supplemented with deliberate external rest for such patients, when they are kept away from the action of constant and strong stimuli emanating from the surroundings, kept away from other, restless patients."*

* I. P. Pavlov, *Twenty Years of Objective Study*, pp. 726-27.

The psychiatric clinic at Pavlov's laboratories was organized in conformity with these principles; it was more like a comfortable sanatorium than a psychiatric establishment.

Moreover, the daily routine and regimen in the clinic were fully aimed at ensuring maximum rest for the patients.

The same principles were observed in the work of the Kharkov clinic headed by V. P. Protopopov, who termed those principles "protective therapy."

We now turn to the research carried out in Pavlov's psychiatric clinic during his lifetime and after his death.

8

THE MAIN LINES OF RESEARCH IN PAVLOV'S PSYCHIATRIC CLINIC DURING HIS LIFETIME AND AFTER HIS DEATH

The experimental and experimentally-clinical research carried out in the psychiatric clinic, which was created at the Pavlov laboratories and which served as a base for his clinical patho-physiological work, can be divided into three different groups.

One group covered a number of experimental investigations aimed at studying the pathological disturbances of the cortical dynamics in the neuropsychical diseases which chiefly attracted Pavlov's attention.

The second group of experimental investigations was specially devoted to the study of neuro-dynamic derangements in schizophrenia.

Finally, the third group of experimentally-clinical investigations was closely connected with the clinical treatment of schizophrenia.

The first group included experimental investigations of the cortical dynamics in cases of progressive paralysis

(P. Y. Yapontsev), in epilepsy accompanied by neuropsychical disturbances (N. V. Vinogradov), in hysteria (V. K. Faddeyeva and Y. A. Povorinsky), in manic-depressive psychosis and various depressive states (V. K. Faddeyeva) and in involutional psychoses (V. P. Golovina).*

Despite obvious distinctions between the disturbances of the cortical dynamics revealed in the diseases just mentioned, these disturbances possessed one sharply expressed common feature: in all cases there was a considerable derangement of the coupling function of the cerebral cortex, even in its simplest form, i.e., the function of linking the newly acquired temporary conditioned connections, or new cortical associations, the function of adaptation to changes in the surrounding medium.

In severe forms of hysteria new cortical connections, although emerging quickly, were always distinguished by insufficient stability, inadequate firmness and evenness. The internal, active inhibitors proved particularly unstable; they were easily disinhibited, especially in affective states. But the phenomena of passive inhibition (external and transmarginal) were usually strongly marked and manifested themselves in quick fatigability and drowsiness, as well as in high distractibility (V. K. Faddeyeva and Y. A. Povorinsky).

In the depressive phase of circular psychosis new cortical connections appeared very slowly, while internal inhibitors, on the contrary, appeared quickly and easily.

* The method of the somewhat modified "simple psychical reaction" (the speech method of A. G. Ivanov-Smolensky) was used in all investigations mentioned; in some cases the electro-cutaneous defensive method (of V. P. Protopopov) was also used with the registration not only of movements but also of the pulse and respiration, and in some cases—the so-called associative experiment (mainly for investigation of the second signalling system).

In moderate forms of the manic phase new cortical connections, new associations emerged impetuously, while active inhibitors, on the contrary, emerged with great difficulty. In strongly pronounced manic states diffused transmarginal inhibition appeared in the second signalling system (evolutionarily younger and more susceptible to injury), expressed in drastic retardation and inferior quality of the verbal associations together with disinhibition of the highly affective gesticulation. Subsequently, in the first signalling system the ultra-paradoxical phase was observed with inhibition of the higher cortical functions and disinhibition of the lower, primitive functions (V. K. Faddeyeva).

Experimental study of the peculiarities of derangements in the first and second signalling systems and in their interrelations, as well as of the disturbances of the vegetative nervous activity, made it possible to establish not only a number of common but also of differing features in depressive states of different origin (circular, schizophrenic, involutional and reactive depressions); this has contributed to the differential diagnosis of these diseases (V. K. Faddeyeva).

In involutional depressions, along with a patent retardation of the development of new cortical connections, as well as of internal inhibitors, there were observed strong phasic phenomena (the equalization and paradoxical phases), general pathological inertness of the cortical processes, and particularly severe disorders in the second signalling system (V. P. Golovina).

A considerable number of experimental investigations performed in the clinic, as already mentioned, were devoted to schizophrenia and especially to its catatonic form.

Investigation of the muscular tone at night time in stuporous catatonics (with phenomena of catalepsy or general rigidity) showed extreme unsteadiness and fra-

gility of their night sleep; as a matter of fact in most cases the demarcation line between wakefulness and sleep was fully obliterated; when the patient did fall asleep for a short period, the disappearance of general derangement of the muscular tone was always observed (N. V. Vinogradov, V. P. Golovina, F. P. Mayorov, I. O. Narbutovich).

Investigation of the activity of the vegetative nervous system in inhibited catatonics (with the help of various external stimuli and pharmacodynamic tests) revealed frequent vegetative dystonias, a tendency towards inverted reactions, and often a lowered reactivity with a parasympathetic predominance (V. P. Golovina, A. I. Stchasny and others). This produced the impression that here the phasic phenomena spread also to the system of vegetative subcortical centres.

In such patients the coupling function of the cortex was in most cases greatly disturbed: the establishment or consolidation of new cortical connections was completely or almost completely impossible. It is worth noting that in some cases, where a somatic motor conditioned reaction could not be produced, it proved comparatively easy to obtain a conditioned vegetative reaction (respiratory or cardio-vascular).

Paranoid schizophrenics quite easily established positive and inhibitory cortical connections, which, however, were often subjected to induced inhibition (negative induction) on the part of delirious and hallucinatory pathodynamic structures (A. P. Selheim, N. N. Traugott, N. G. Harzstein).

In catatonics the inhibition often irradiated also to the unconditioned reflexes—defensive and orienting; here, while the motor somatic component was intact, the vegetative component in the shape of normal changes of respiration and pulsation was sometimes wholly absent (I. O. Narbutovich, V. K. Faddeyeva, A. I. Stchasny).

Often, along with inhibition of the higher unconditioned reactions, there took place a disinhibition of the primitive, rudimentary reflexes, such as the grasping, crawling and sucking reflexes (I. O. Narbutovich). These reflexes disappeared with the disappearance of the stuporous state, which testified to the fact that their disinhibition was of a functional, temporary nature.

A combined investigation of the cortical dynamics and peripheral chronaxy (of the common flexor of the fingers), carried out in the laboratory of our clinic for the first time showed that, whereas in healthy persons conditioned excitation and conditioned inhibition are always accompanied by strictly definite changes of the peripheral chronaxy, in schizophrenics in similar cases these changes were of an entirely chaotic character and produced highly variegated results observed not only during each successive experiment, but even during one and the same experiment (E. A. Yakovleva).

Thorough observation and the experimentally-clinical patho-physiological investigation of schizophrenics-catatonics and paranoid schizophrenics resulted in the establishment of a number of new facts (A. G. Ivanov-Smolensky):

a) The states of catatonic stupor, notwithstanding their seeming external uniformity, include a number of essentially differing variations; these distinctions depend on different correlations in the derangement of the somatic and vegetative functions (the latter may be in a state of depression, excitation and dissociation), on the irradiation of inhibition to different depths, to different levels of the brain stem, and on different localization of diffused inhibition in the cerebral cortex;

b) Diffused inhibition in the cortex in stuporous states may be of a twofold character; in some cases it is a widespread negative induction (induced inhibition), circuiting the complex dynamic structure—the seat of in-

tense stagnant, inert excitation, usually reflecting certain affective states connected with the past experience of the patient who is fully concentrated on them; the powerful negative induction completely dissociates the patient from the surroundings to which he becomes, as it were, blind and deaf; in other cases the inhibition is concentrated in the cortex, mainly in the motor area, which makes any movement of the patient impossible, but at the same time does not prevent him from perceiving his surroundings. Thus, in the first case we have, so to speak, a *receptor* stupor, and in the second—an *effector* stupor.

c) Catatonic mutism is inhibition concentrated in the second signalling system (in some cases mainly in its receptor part, and in others—mainly in its motor part); thorough investigation shows that in some cases it is possible to re-establish social contact with the patients, replacing verbal agents with visual ones (by pictures or written questions and suggestions), and sometimes resorting to figurative gestures and stimulating them in the patients.

d) In speech incoherence (schizophasia) there are pathological derangements of the interaction of the first and second signalling systems with a predominant affection of the last mentioned; in the second signalling system there arise intermediate states between wakefulness and sleep, and sometimes also phenomena of pathological inertness connected with the processes of central irritation evoked by destruction.

e) Schizophrenic delirium is in some cases of a markedly imaginative character; it is often combined with visual hallucinations and thus relates mainly to the first signalling system; in other cases it is predominantly of a verbal nature, i.e., represents a morbid derangement of verbal thinking, sometimes combined with auditory, verbal hallucinations, and consequently is in the main a disturbance of the second signalling system.

f) Phasic phenomena, concentrated in the visual (rarer in the auditory) area of the cerebral cortex, underly the oneiric, dream-like hallucinations.

g) When local phenomena of pathological inertness of the excitatory process, which determine the stereotyped recurring hallucinations, are concentrated mainly in the visual or auditory areas of the cortex, they usually assume the character of pseudo-hallucinations (being experienced "inside the head"); if the inert excitation spreads also to the cortical projection of the visual or auditory accommodation, the hallucinations are then projected to the outside and assume the character of real hallucinations.

Finally, the last group of investigations, as already mentioned, is closely connected with the therapeutic work of the clinic, to which we shall now proceed.

9

THE WORK OF PAVLOV AND HIS COLLABORATORS IN THE SPHERE OF THE PATHOGENIC THERAPY OF NEUROPSYCHICAL DISEASES

By the end of the last century, and especially in the twenties and thirties of this century, the application of prolonged narcosis in the treatment of mentally diseased (mainly schizophrenics), showing a high and persistent excitation, had become widespread in psychiatry.

In 1934 prolonged narcosis was first applied in the Soviet Union in the clinic of V. P. Protopopov; in subsequent years it was also used by N. A. Shevelev and M. Y. Sereysky jointly with Feldman.*

* The experience of foreign clinics showed that prolonged narcosis (for which mostly somnifene was used at the time) led to a considerable death rate. But in 1934 the Swiss scientists

Having acquainted himself with the problem of sleep therapy as it stood at the time, Pavlov expressed a desire to try this therapeutic method (with the help of Cloetta's mixture) in the psychiatric clinic attached to his laboratories. Proceeding from the concept of protective inhibition, he decided, contrary to all previous methods of sleep therapy, to apply it not in states of excitation, but in those schizophrenic syndromes where the phenomena of protective inhibition were clearly manifest, i.e., first of all in catatonic stuporous and depressive stuporous states, as well as in all other cases of schizophrenia where intermediate states between wakefulness and sleep were distinctly in the foreground.

Pavlov's fundamental therapeutic principle was absolutely clear: in every possible way to promote and strengthen the defensive nervous mechanism which is represented by protective inhibition.

Previously, as a rule, only one or two patients were simultaneously subjected to prolonged narcosis. In Pavlov's clinic a special section accommodating from twelve to fourteen patients was equipped for this purpose. The windows were curtained off so as to prevent the penetration of daylight into the wards and the floors covered with soft cloth deadening the steps of the attendants. Besides, monotonous rhythmic stimuli in the shape of a slowly blinking blue light and the beat of a metronome were introduced. The section was attended by special physicians on duty—by psychiatrists and therapists (under the direction of M. K. Petrova and N. I. Schwarz).

From twelve to fourteen patients were simultaneously subjected to prolonged narcosis (with the help of Cloetta's

Cloetta and Maier published their work (Cloetta M. u., Maier H. W., *Über eine Verbesserung der Psychiatrischen Dauernarcose-behandlung*), in which they recommended a narcotic mixture of their preparation and pointed to its favourable therapeutic action and its allegedly insignificant toxicity.

mixture) for a period ranging from six to twelve days (usually in the middle of the prolonged narcosis course the patient for a period ranging from twelve to twenty-four hours was not given the narcotic mixture; this was done in order to reduce its toxicity and the patient continued to sleep, as it were, under his own momentum).

In his reply to the personnel of the Kiev psychiatric hospital, who had asked for his permission to rename their hospital after him, Pavlov pointed out that he was "astonished at the favourable results" obtained by his clinic in the field of narcotic sleep therapy and that he regarded this as "an encouraging and promising start in bringing together experimental physiology and pathology of the higher nervous activity and the clinic of nervous and mental diseases."*

Of great interest are Pavlov's statements concerning the general regimen and the care of patients in psychiatric medical establishments. "Although enormous progress has been made since olden times up to our day in the treatment of the mentally ill, still, I think, something remains *to be desired* in this respect. To keep patients, already possessing a certain degree of self-consciousness, together with other, irresponsible patients, who may subject them, on the one hand, to strong stimulations in the form of screams and extraordinary scenes, and, on the other hand, to direct violence, in most cases means creating conditions which to a still greater extent enfeeble the already weak cortical cells. Moreover, the violation of the patient's human rights, of which he is already conscious and which partly consists in restriction of his freedom, and partly in the fact that the attendants and medical personnel naturally and almost inevitably regard him as an irresponsible person, cannot but strike further heavy blows at the weak cells. Consequently, it is necessary as

* *Izvestia* and *Pravda*, February 4, 1936.

quickly and as timely as possible to place such mentally diseased in the position of patients suffering from other illnesses which do not offend human dignity so manifestly."*

In keeping with this humane suggestion of Pavlov, we have organized at his laboratory a psychiatric clinic which is more like a sanatorium than a psychiatric medical establishment.

After Pavlov's death the clinic continued the elaboration of problems relating to active therapy of schizophrenia; however, it abandoned Cloetta's mixture because of its high toxicity, and replaced it by sodium amytal possessing low toxicity, sometimes in combination with paraldehyde. At the same time, instead of prolonged narcosis, which usually assumed a severe course, the clinic applied *prolonged narcotic sleep*, always maintaining it at the level of sound, deep natural sleep and never bringing it to a state of narcosis.**

It transpired, however, that the effect of prolonged narcotic sleep, especially in cases where the illness lasted more than six to twelve months, was inferior to that of prolonged narcosis. Thoroughly observing the phenomena of prolonged narcosis, we paid attention to the sharp and sometimes violent vegetative changes which are peculiar to it (acceleration of the pulse rate and respiratory rhythm, heightened secretion of sweat, rise in temperature, changes in the leucocytal formula, etc.), and which in some cases, unfortunately, are accompanied by complications, mainly in the respiratory and cardio-vascular systems.

We also know that the most effective of all active methods of treatment applied in psychiatry, such as

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* I. P. Pavlov, *Twenty Years of Objective Study*, p. 515.

** Described in detail in the symposium *Prolonged Narcosis in Schizophrenia* published by the Institute of Experimental Medicine of the U.S.S.R. in 1940.

hyperpyretic (for example, sulphosine) therapy, as well as insulin shock and convulsive therapy, are, in their turn, characterized by powerful vegetative changes, by phenomena, as it were, of vegetative mobilization, having, in the broad sense, a vegetative rearrangement and detoxicating effect. However, all these methods, like prolonged narcosis, prove very harmful for the patients and are not free from somatic complications.

This circumstance impelled us to seek for new therapeutic methods, mainly in cases where prolonged narcotic sleep alone is not sufficiently effective, i.e., where the rehabilitation of cortical activity resulting from profound protective inhibition proves inadequate or unsteady due to the fact that the intrasomatic source of neuro-intoxication has not been radically eliminated.

Although we rejected the method of narcosis, we decided to combine prolonged narcotic sleep with methods of treatment which change the vegetative functions, however, easing them as much as possible and thereby avoiding somatic complications. For instance, using not more than ten injections of sulphosine instead of the usual 20-30, we combined each injection with an amytal sleep for 36 hours (P. Y. Yapontsev); in other cases six or seven days' amytal sleep was combined with 15-20 injections of insulin which evoked considerable vegetative changes, without, however, bringing the patient to a shock or to a comatose state (I. O. Narbutovich and Y. A. Povorinsky); finally, we shortened the course of convulsive therapy (cardiazol and electroshocks) from 20-25 to 4-5 fits, and combined each of them with amytal sleep lasting from 24 to 36 hours (A. I. Stchasny and N. G. Harzstein).

It transpired that the effect of these synthetic or combined forms of therapy not only was not below that of the methods of the active therapy generally accepted in psychiatric clinics (prolonged narcosis, insulin shock,

convulsive and hyperpyretic therapy), but in certain respects was even greater. Also of particular significance was the fact that these methods did not lead to any serious somatic complications.

Lastly, combined therapy, which is less protracted, considerably eased and free from narcosis and insulin coma, proved more humane than the other forms of active therapy.

Thus, in most cases where prolonged narcotic sleep alone was insufficient, we resorted to various forms of synthetic or combined therapy, more often combining amytal sleep with insulin hypoglycemia; at the same time we used other methods, which were, however, firmly based on the principle of combined, synthesized action of the nervous mechanism of protective inhibition and the nervous mechanism of vegetative mobilization.

In connection with active therapy a number of experiments were carried out in the clinic with the aim of extending the knowledge of the nervous mechanisms of the therapeutic effect and of studying the processes of restoring the functions of the nervous system as a result of medical treatment (P. Y. Yapontsev, A. P. Selheim, N. G. Harzstein, I. O. Narbutovich, V. P. Golovina, A. I. Stchasny, N. A. Zhurikova and others).

It was also found that by replacing from time to time insulin or cardiazol injections by a physiological solution it was possible to obtain in the patients, through the mechanism of temporary, conditioned connection, changes similar to those obtained with the help of these substances (Y. A. Povorinsky, T. V. Strokina, N. G. Harzstein). This, in particular, made it possible to reduce the number of insulin injections in the course of treatment.

The outbreak of the Great Patriotic War in 1941 and the siege of Leningrad interrupted this work, although even during the siege the clinic succeeded in carrying out a number of experimental investigations

Those of the clinic's staff who were evacuated continued their research in evacuation hospitals, concentrating on closed traumas of the brain (Z. L. Sinkevich, V. K. Faddeyeva, A. G. Ivanov-Smolensky and others).

The basic conclusions of their almost three years' work are essentially as follows: there is every reason to believe that the profound and diffused inhibition, which embraces the central nervous system immediately after, or to be more precise, at the moment of severe trauma (air contusion, concussion of the brain, injury to the head) and which manifests itself in loss of consciousness, in general hyporeflexia and even areflexia, as well as in a transient depression of the vegetative functions (slow and feeble pulse and respiration) is nothing more than protective inhibition spreading not only to the whole cerebral cortex, but also to the lower levels of the central nervous system.

Gradually becoming weaker and concentrating mainly in the higher parts of the brain, it, however, makes itself felt during a more or less considerable length of time in the shape of phenomena of general motor inhibition.

First of all the subcortical regions are liberated from this irradiated diffused inhibition; the cortical cells, which are most delicately differentiated, most reactive and at the same time most susceptible to injury, are the last to be disinhibited. Protective inhibition tends to persist longest in the system of auditory centres, the highest part of which is the auditory area (acoustic analyser) of the cerebral cortex. It should be borne in mind that the acoustic analyser is not only subjected to the same noxious influences experienced by all other parts of the brain (air contusion, concussion), but at the moment of the trauma it suffers a kind of additional traumatic strain in the shape of ultra-strong stimulation evoked by the deafening acoustic effect of the explosion.

But in man the acoustic analyser is the seat of the sensory area of speech which in respect of association is closely connected with the motor-kinesthetic area of speech ("the motor speech centre"). In their turn, these two areas are the basic structural components of the second signalling system of the cortex.

It is natural, therefore, that in its reverse development the widely irradiated protective inhibition should be most persistent in the evolutionarily younger, and at the same time most traumatized region, as well as in the regions very closely connected with it functionally. In this way there appear phenomena of contusive-commotional surdomutism, in which the inhibition usually spreads also to the subcortical centres of phonation, thus producing the picture of surdoaphonia.

In the course of the reverse development of protective inhibition, with the gradual disinhibition first of the subcortical regions, then of the cerebral cortex, and finally, of its auditory-speech area, the functional interrelations of the different parts of the brain are considerably disturbed. On the one hand, subcortical activity prevails temporarily over cortical activity which is not yet fully liberated from inhibition; this, in particular, is expressed in the intensification, disinhibition and dissociation of the vegetative functions of the interbrain, owing to weakening of the cortical influences which regulate and control them. On the other hand, the entire direct—speechless—activity of the cortex, i.e., the first signalling system becomes predominant over the external and internal (verbal thinking) activity of the "speech system" (the second signalling system).

But as we already know, in Pavlov's view, the predominance of subcortical functions over cortical ones and of the first signalling system over the second is the most characteristic feature of hysterical syndromes.

A sharply increased emotivity, convulsive discharges, violent affective outbursts, not controlled by the higher inhibitory process, a tortuous, imaginative concrete reproduction of past painful experiences—all these phenomena are accounted for by this temporary (and often persistent) predominance. In cases of rapid reverse development of diffused protective inhibition, disturbance of the dynamic correlations in different parts of the brain, as a rule, is not observed; the neurotic stage of the disease in these cases is characterized merely by a somewhat lowered functional threshold of the working capacity of the cortical cells, by a pathological lability of nervous excitation and its heightened exhaustibility, expressed in excitatory weakness, quick fatigability, impeded concentration and other neurasthenic symptoms.

On the basis of these patho-physiological data a special therapy was worked out. In the first stage of treatment it consisted of a number of measures aimed at the maximum promotion of self-protective tendencies in the nervous system (absolute peace, rest-cure, extensive administration of narcotic and sedative remedies ensuring an improvement and considerable prolongation of the daily sleep up to ten or fifteen hours), especially in cases of persistent surdomutism. In the second stage the therapy consisted in tonic treatment contributing to the regulation of the vegetative functions. In the course of this treatment small doses of phenamine were often applied, as well as functional therapy and stimulating psycho-therapy. The favourable effect of this therapy told with particular force upon the phenomena of surdomutism which usually quickly disappeared.

During and after the war E. A. Asratyan and his collaborators widely applied sleep therapy which produced similar good results in the treatment of closed and open traumas of the brain, as well as of some other disturbances (phantom pain, traumas of the spinal cord,

etc.); for this purpose they used special narcotic mixtures of their own preparation. Basing his work on Pavlov's concept of protective inhibition, E. A. Asratyan stresses the interesting fact that, according to a number of investigators, the amount of oxygen absorbed by the nervous cells does not diminish under the action of narcotics which evoke inhibition of their external activity. Considerable work in the field of sleep therapy of brain traumas was done during the war also by A. O. Dolin. A number of scientists successfully applied this therapy under causalgia (E. A. Asratyan, F. A. Andreyev, B. N. Seraphimov and others). It also proved successful in the case of certain skin diseases (M. K. Petrova, K. L. Poliakov and others).

The research carried out by M. K. Petrova and M. A. Ussievich convincingly showed that various somatic, vegetative, and trophic disturbances evoked by collisions, breakdowns, overstrain of the higher nervous activity and connected with experimental neuroses, usually disappeared when the functional derangements of the cortical dynamics were successfully removed.

Naturally, this gave birth to the idea of applying sleep therapy not only in neuropsychical diseases, but also outside the psychiatric clinic, namely, in all cases when various somatic disturbances develop as a result of overstrain of the cortical processes, even when the latter do not lead to sharply expressed reactive states.

Sleep therapy has become widespread in the clinic of internal diseases, in surgery, obstetrics, gynaecology and in other clinical branches.

However, the limits of its application and the indications of them have not yet been sufficiently specified and require further thorough investigation. The application of sleep therapy beyond the limits indicated by Pavlov himself, and without sufficient pathogenic justification, especially when it is not based on Pavlov's theory

of protective inhibition, leads simply to the vulgarization of this valuable therapeutic method. Inadequately elaborated and insufficiently grounded attempts to apply it may easily discredit this method of treatment.

Nevertheless, when sleep therapy is pathogenically well-grounded, it usually proves its value.

Today problems of sleep therapy attract the attention of representatives of diverse clinical specialities (Chernorutsky, Andreyev, Bakulev, Busalov, Miasnikov, Nikolayev, Nesterov, Bierman, Snezhnevsky, Kerbikov and others).

Reverting to the question of our post-war research, we must point out that in the psychiatric clinic it has been devoted to the following three basic subjects: a) the tardy consequences of brain traumas, b) the reactive states, and c) the narcomanias (mainly chronic alcoholism). We shall dwell briefly on this research, mentioning only some of its aspects.

Experimental-clinical investigation of cortical dynamics in tardy after-effects of closed brain traumas showed that considerable disturbances of the mobility of the cortical processes and an obvious predominance of the processes of passive (unconditioned) inhibition are common features of these diseases. The phenomena of pathological inertness usually do not bear the character of local disturbances, but assume a diffused, irradiated form. The intensified phenomena of negative induction are most manifest among various forms of passive inhibition. The interaction of the first and second signalling systems is deranged, the first predominating over the second. The above-mentioned changes in the mobility of the cortical processes and passive inhibition are most sharply expressed in the second signalling system.

Nevertheless, persistent training of the cortical functions with the help of certain methods considerably softens these defects.

Here, too, sleep therapy produces good results (N. G. Miroliubov).

Study of derangements in the cortical dynamics in cases of reactive depression revealed a relatively frequent emergence in the first signalling system of intermediate states between wakefulness and sleep, or phasic states (the paradoxical and equalization phases).

Thorough investigation of the conditions under which these states emerge showed that the following factors are responsible for them: fatigue, which develops in the course of unduly protracted experiments and connected with transmarginal inhibition; the reshaping of even simple dynamic stereotypes, i.e., the necessary adaptation to new conditions; and finally, the application before the experiment, in the course of the so-called associative experiment, of affectogenic verbal stimuli, reminding the patient of his psychical traumas. This, to a certain degree, was instructive in relation to the therapy and neuro-hygiene (medical regimen) of such patients (N. G. Harzstein).

Comparative study of the cortical dynamics in cases of alcoholic delirium and chronic alcoholic hallucinoses showed that in the first case the hallucinations, which here mainly relate to the first signalling system, develop on a background of intermediate states between wakefulness and sleep; but in the second case they take the form mainly of verbal hallucinations (i.e., develop in the second signalling system) and are connected with pathological inertness of the nervous processes. As a result of experimental reinforcement of the processes of excitation, or, on the contrary, of the processes of internal inhibition in the first signalling system, there were observed a number of changes in the subject matter of the verbal hallucinations which take place in the second system.

Under the action of the usual therapeutic doses of adrenalin, phenamine and atropine, the verbal hallucinations weakened and for a time even fully disappeared. A similar effect was observed after deep and prolonged sleep produced by amytal, veronal or chloral hydrate (M. I. Seredina).*

Investigation of the higher nervous activity in severe forms of chronic alcoholism disclosed considerable derangements of the cortical dynamics (weakening of the coupling function, pathological diminution of the mobility of the cortical processes, insufficiency of the processes of internal, active inhibition, etc.). Morbid derangements were most pronounced in the second signalling system.

The smell and taste of alcohol were repeatedly combined with injections of apomorphine or emetine, producing phenomena of nausea and vomiting, which later began to emerge through the mechanism of temporary conditioned connection solely under the action of the smell or taste of the alcohol; in this way it proved possible to obtain in many cases of chronic alcoholism a durable remission lasting many months, and even complete recovery.** In other cases a similar result was obtained by repeated combination of the smell and taste of alcohol with the verbal suggestion of negative emotional reactions (sense of disgust, nausea) in a series of hypnotic seances (I. V. Strelchuk).

Thus, on the one hand, the research was in the main directed to the study of general disturbances of the cortical dynamics in various diseases, and especially to investigation of the deranged correlations between the

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* Analogous facts were observed earlier by I. V. Strelchuk and partly by E. A. Popov.

** The first attempt to use the mechanism of conditioned connection in treatment of chronic alcoholism, was made before the Great Patriotic War by the Soviet psychiatrist I. F. Sluchevsky.

first and second signalling systems, which contributed in large measure to an understanding of the pathogenic nervous mechanisms of these diseases; on the other hand, it was devoted to a search for physiologically and patho-physiologically grounded methods of treatment.

In recent times we have again turned to prolonged sleep therapy in connection with the problems relating to a more precise definition of the indications for its application, and the extension of its administration, and also to problems relating to synthetic combined therapy.

Particularly favourable results have been obtained with the help of different forms of sleep therapy in reactive states, certain acute and chronic alcohol psychoses, tardy after-effects of brain traumas in traumatics decompensated as a result of difficulties encountered in life, in neurotics, and finally, in states of morphine abstinence (Harzstein, Seredina, Miroliubov, Sinkevich, Strelchuk). In many cases narcotic sleep was combined with hypnotic sleep (Strelchuk).

It should be stressed that, as a rule, prolonged sleep therapy was applied by us for the purpose of reinforcing and deepening the existing phenomena of protective inhibition. In other words, when applying sleep therapy we strictly adhered to Pavlov's pathogenic principle.

The problem of the age patho-physiology of the higher nervous activity attracted our attention long ago, but only in recent years have we succeeded in carrying out preliminary, tentative work in this field.

Investigation of the nervous activity of neurotic children (of pre-school and school age) has shown that in conditions of general neuroses, along with disturbances of the cortical dynamics there are always present, and very often sharply expressed, derangements of the reactivity of the vegetative nervous apparatus, which in such cases is usually most unsteady and tends to inverted reactions (T. V. Strokina, Z. L. Sinkevich).

As proved by the study of the cortical dynamics, in certain acute infectious diseases in children (lobar pneumonia, scarlet fever, etc.), in cases of average and considerable severity, during the so-called sympathicus-phase (according to A. A. Koltypin) distinct phenomena of transmarginal protective inhibition are observed in the cortex (R. M. Pen, N. I. Kozin), which protect the cortical cells from neuro-intoxication.

Adhering to the basic principles of Pavlov's patho-physiology of the higher nervous activity, we, on the one hand, have devoted our clinical and patho-physiological work to the problem of pathological changes in the neuro-dynamics with the aim of attaining a proper understanding of the pathogenic nervous mechanisms underlying different illnesses, and also of improving and rendering more precise the differentially diagnostic and prognostic criteria for clinical research; on the other hand, we have endeavoured to find neurophysiological ways for the elaboration of a pathogenically grounded therapy, to study the nervous mechanisms of therapeutic influences and the rehabilitation of the disturbed functions caused by them.

The research already carried out by us in this field, is but the initial stage of our work and is far from being free of errors; it is but our first attempt to comprehend the vast complexity of the phenomena under investigation, and what is more, to bring these phenomena under efficient control.

Our dissatisfaction with the results achieved so far is particularly keen when we compare them with the broad prospects which Pavlov's patho-physiology of the higher parts of the central nervous system opens up before every research worker in this field of science.

CONCLUSION

The theory of the higher nervous activity was first applied to man in 1907 by N. I. Krasnogorsky, one of Pavlov's oldest disciples, when he made initial attempts experimentally to investigate the cortical dynamics in children. But in the field of neuropathology and psychiatry this theory was first introduced by V. M. Bekhterev and his school (in 1908-1909). One may not agree, and with good reason, with Bekhterev's tendency to oversimplify such a complex problem, on the one hand, and, on the other, to make too sweeping and ungrounded generalizations in the attempt to solve this problem. At the same time, however, we must admit his unquestionable and indubitable merit—he was the first representative of neuropathology and psychiatry who rightly appraised the vast prospects opened up for these branches of medicine by Pavlov's theory. In doing so he, undoubtedly, rendered a great service to Russian science.

Later on our neuropathologists and psychiatrists frequently resorted to the theory of the higher nervous activity in order to solve one or another particular problem. It suffices to recall, for instance, the works of M. M. Assatiani (1913), M. I. Astvatsaturov (1918), V. P. Ossipov (1923), A. K. Lenz (1923), L. V. Blumenau (1926).

In the Ukraine, mainly in the twenties and thirties of this century, much attention was given by V. P. Proto-

popov (outstanding representative of V. M. Bekhterev's school) to the problem of bringing Pavlov's theory into close contact with psychiatry.

Mention should also be made of Protopopov's co-workers A. P. Prussenko, E. A. Popov and N. P. Tatarenko. In the Ukraine much work has been done along these lines by K. I. Platonov, who is still carrying on his research.

We have repeatedly emphasized that from the very beginning of his joint work with S. P. Botkin and throughout his further scientific activity right until the last days of his life, Pavlov always sought to bring physiology into closer contact with medicine and at the same time to introduce into both one and the other the idea of nervism. One cannot but admit that his theory of the higher nervous activity constitutes the most complete and brilliant embodiment of this idea.

We have seen that the study in Pavlov's laboratories of pathological states induced in animals by the destruction of different parts of the cerebrum greatly contributed to a correct understanding of the general and local disturbances of the neuropsychical activity observed in various organic lesions of the brain; this study elucidated the nervous mechanisms underlying the process of restoration of the deranged functions.

Experimental investigation of pathological states caused by "difficult tasks," collisions, overstrain of the cortical process, and external situations, which are of maximum complexity for the nervous system, contributed greatly to an understanding of the neuro-dynamic mechanisms responsible for the action of "psychogenic factors" in the aetiology not only of various neuropsychical, but also of many somatic diseases.

The theory of the types of higher nervous activity creates the pre-conditions for a full and radical revision, from a new angle, of the utterly obsolete and methodo-

logically erroneous concepts of a "psychical constitution," which overestimated the role of heredity, opposed the mental to the somatic, or were based on the principle of psycho-physiological parallelism.

It should be also stressed that Pavlov made the first attempt to draw in neuropsychical disturbances a demarcation line between the symptoms of the disease in the proper sense of the words and the nervous mechanisms of self-defence against the morbific influences elaborated in the process of evolutionary development (the concept of protective inhibition).

He was also the first to show that general and local disturbances take place not only in organic lesions of the cerebral hemispheres, where they were precisely differentiated by him, but also in functional pathological states of the higher nervous activity (general experimental neuroses and local derangements in "isolated pathological points or areas").

In a number of experimental investigations carried out by his laboratories he disclosed with the same precision the significance of the internal medium of the organism and of the disturbances artificially induced in it for the work of the cerebral cortex, which depend, moreover, on the various types of nervous system.

Modelling on animals, reproducing and investigating various neuropsychical disorders on the simplest experimental patterns, establishing the common and differing features of pathological states of the higher nervous activity in man and in animals, Pavlov laid the foundation for an evolutionary-genetic and comparative pathophysiology of the higher parts of the central nervous system.

As we know, in his study of cerebral disturbances which was carried out both in the laboratory and in the clinic, in conditions of close interaction, Pavlov invariably strove experimentally to elaborate pathogenically

grounded methods of treatment of neuropsychical diseases.

However, it would be anachronistic to speak nowadays of the significance of physiology and patho-physiology of the higher nervous activity solely for the nervous and psychiatric clinic. The enormous influence exerted by cortical functions on the vegetative nervous system and even on the whole internal medium, the enormous influence exerted by the higher nervous processes on the prevention, course and reverse development of most diverse somatic disturbances, the dependence of these disturbances on pathological changes in the work of the higher parts of the central nervous system and the significance of its protective mechanisms for the prevention and elimination of somatic diseases—all this is now indisputable (M. K. Petrova, K. M. Bykov, M. A. Ussievich, A. O. Dolin and others).

On the other hand, many of the researches made by the Pavlov school, a considerable part of which had been conducted during his lifetime, laid bare the negative influence of the various somatic disturbances on the work of the higher parts of the brain and revealed the process of development of adaptive nervous mechanisms, which compensate and restrict these harmful influences emanating from the internal medium of the organism and disturbing the work of the higher parts of the nervous system.

The works of K. M. Bykov, M. A. Ussievich, and particularly of M. K. Petrova and of a number of other disciples of Pavlov strikingly testify to the widespread application of his ideas of nervism not only in physiology but also in pathology.

At the same time it is impossible not to note with great satisfaction that Pavlov's scientific ideas exert an ever growing influence on general pathological physiology (S. M. Pavlenko, P. D. Gorizontov, V. A. Negov-

sky, I. A. Piontkovsky, S. V. Andreyev and others). These ideas are steadily penetrating into clinical medicine.

However, it would be erroneous to disregard the great difficulties which still confront the further development of the patho-physiology of the higher parts of the central nervous system and its introduction into the clinic. Besides, it is not only a question of the complexity of the problem itself, but of the danger of a certain conservatism, on the one hand, and of over-simplification and vulgarization on the other.

In one of his last lectures devoted to the activity of the cerebral hemispheres, Pavlov warned future workers in this field of the extraordinary difficulties which they would encounter. He concluded his lecture with these words: "On the whole this new field of physiological research is indeed highly fascinating, and satisfies two concomitant cravings of the human mind—the striving to acquire newer and newer truths, and the protest against any claim to finality in the knowledge already gained. . . ."*

We have every reason for saying that the same thing applies to the pathological physiology of the higher nervous activity created by Pavlov.

Boundless vistas are opening up in this field for Russian science, for future generations of scientific workers and, above all, for our medical youth, the Soviet youth, to whom Ivan Petrovich Pavlov not only addressed his last will, inspired with lofty and brilliant thought, but also bequeathed a great scientific legacy.

I. P. Pavlov, *Lectures*, p. 344.

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3. TO ESSAY III AND CONCLUSION

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